MEMOIRS

OF THE

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MEMOIRS

Neele sculp.t

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MEMOIRS

OF THE

LITERARY AND PHILOSOPHICAL SOCIETY OF MANCHESTER.

A brief COMPARISON *of some of the principal* ARGUMENTS *in Favour of* PUBLIC *and* PRIVATE EDUCATION. *By* THOMAS BARNES, D. D. *Read May* 7, 1783.

THERE are few queſtions more important, when conſidered in every point of view, than thoſe which relate to EDUCATION. Allowing the original differences ſtamped upon human minds to be great, yet education marks far greater and ſtronger lines of diſtinction, between one mind and another. It was education, which formed the poliſhed and lettered ſage, in the æra of the higheſt Grecian ſplendour. And it is education, which moulds the ſavage Indian for the deſert.

"Dii Immortales!* Homini Homo quid præſtat!
Stulto intelligens! Quid intereſt!*

It is generally ſaid, in praiſe of the preſent age, that it is more ſenſible, than any which have preceded, of the immenſe importance of education. I mean not to detract from the real merit of my cotemporaries, by hinting a ſuſpicion, that ſomething muſt be abated of this high compliment. The *object* and *end*, upon which modern education is often employed, will not, I fear, do the greateſt honour to our diſcernment, or our piety.

Among the various plans of education, each of which has had its warm admirers, and ſanguine advocates, the parent, anxiouſly intereſted for the beſt welfare of his SON, (for I wiſh to confine the preſent ſubject to BOYS,) is often greatly at a loſs which to prefer. There are, probably, advantages and diſadvantages peculiar to every ſyſtem. The point to be wiſhed for, is, to balance theſe ſo juſtly, one againſt another, as to form the proper concluſion.

There are not a few, both in antient and modern times, who contend earneſtly for a PUBLIC ſcheme of education. There are others, perhaps an equal number, who object as earneſtly *againſt* it. We muſt imagine the general views of thoſe, who embrace the oppoſite ſides of

* Terence Eun. Act. II. Sec. 2.

this

this queſtion, to be exactly the ſame. But, they conſider the ſeveral ſchemes, in different aſpects.

I have not the vanity to hope, that I ſhall be able to offer a ſingle argument, which has not been repeatedly canvaſſed. My utmoſt wiſh, in chuſing this ſubject, was, not to offer ſomething new; but to throw out a few hints, merely by way of introducing a queſtion, than which none greater and more intereſting has been, or, by our laws, can be agitated in theſe meetings.

That we may ſpeak with preciſion on this ſubject, it will be neceſſary to define the terms, PUBLIC and PRIVATE education.

By PUBLIC EDUCATION, we mean, education at a large public ſchool, conſiſting of perhaps two or three hundred boys, ſuch as ETON or WESTMINSTER; where the boys live in ſome common apartments, deſtined for this uſe, or are boarded in great numbers, with perſons, who only undertake to find them commons and accommodation.

By PRIVATE EDUCATION, we mean, education AT HOME, in the houſe, and under the eye of a parent, or private tutor.

Between theſe two ſchemes, there will be almoſt infinite gradations. Exactly in the mid-way between them, are thoſe ſchools, where boys are boarded in the houſe of a maſter,

 become

become parts of his family, and are not more in number, than he can entirely manage and instruct himself.

We may, perhaps class the prime objects of education, in the following order, beginning with those of less importance, and rising up to those of the greatest. HEALTH—KNOWLEDGE—TEMPER—SELF-GOVERNMENT—MORALS.

I. HEALTH.

It is questioned, whether the carelessness, which must necessarily prevail in a large public school, with respect to the several articles of diet, lodging, dampness, &c.—or the constant careful attention paid to all these circumstances, in the house of a parent, be more friendly to health, and vigour of constitution. It is said, "That an excess of caution injures both the body and the mind, rendering the one puny, and the other pusillanimous." It is added, "That, in a large number of boys, there are more incitements to play, and to those active athletic exercises, which brace the system, and render it robust and hardy."

It must be acknowledged, that the closeness of a nursery is unfriendly to the constitution. But why must we necessarily suppose a boy to be confined to a nursery, in his father's house? May he not be accustomed, *at home*, to any degree of hardiness, at the pleasure of the parent

parent? And are not the principles and conduct of parents, in fact very different? Nor will sufficient incitements to play be wanting, if properly atended to, and improved.

With respect to health, then, a boy *may* have all the advantages, without the many disadvantages, attending a more public plan. And, from what I have observed of life, I should be ready to conclude, that children, who have been educated upon the system of extreme carelessness, in these particulars, have not appeared more vigorous and healthy, when they have grown to maturity.

II. KNOWLEDGE.

It is urged, in favour of public education, "That emulation, that strong and noble principle, when well managed, is more likely to be felt in its proper influence, where there are many, than where there are few competitors. The numbers, and the abilities of the candidates sharpen the edge of genius and of industry, and thus push on the youthful mind to superior excellence."

It may, perhaps, be said, on the other hand, "That to the boy of more brilliant parts, and who stands at the head of his class, the argument from emulation may be allowed. But, that these will be comparatively few; and that to others, who are not able to attain this honour-

able elevation, it will be reverſed, for that its influence will tend to diſcouragement and depreſſion." It may be added, "That, in large ſchools, boys are neceſſarily connected together in claſſes, like horſes in a carriage; that they cannot move on beyond a certain pace; and that this pace muſt be accommodated to the parts and quickneſs of the moſt indolent and ſtupid in the claſs; or elſe, it will be, for one boy in the claſs too quick, and for another, too ſlow. The conſequence will be almoſt equally prejudicial to both. The one is puſhed forward beyond his ſpeed; he is liable to be continually puniſhed for no fault; or hurried on through ſubjects, of which he has not been able to gain any clear and competent knowledge. The other is kept down from thoſe attainments, to which he might otherwiſe have aſcended. This conſtant and wretched clog, it may be ſaid, will be prevented, by having every boy to ſtand ſingle; or, at leaſt, by matching boys of equal capacity together, who may thus be urged forward exactly according to their ſtrength, neither dejected by the ſuperior genius of one, nor fettered by the greater dullneſs of another."

To theſe arguments it may, I think, with great force, be added, "That, in a very large number of boys, there will always be as many, or more, of thoſe who do not excel, as of thoſe who

who do. If, therefore, the one may be ſuppoſed to animate, or to aſhame, the other may, with equal truth, be ſuppoſed to keep thoſe in countenance, whoſe abilities are not ſo bright, or whoſe induſtry is not ſo unremitting."

In vindication of the order, which I have aſſigned to KNOWLEDGE, it may be obſerved, that the great end of mental cultivation is, to give that exerciſe and habit to the various powers of the mind, which may enable them to act hereafter, in all the affairs of human life, with the greateſt advantage. It is not merely, the *quantity* of ideas acquired, but the *ability* obtained by the ſoul, of thinking, reaſoning, and determining rightly, in every event of the changeful ſcene, which is of the greateſt importance.*

III. TEMPER.

Or, perhaps, more properly SOCIAL AFFECTIONS.

It may be urged, by the advocates for PRIVATE ſchools, "That there the heart is longer under the influence of the ſofter and more domeſtic feelings—That reverence to parents, and love to brothers, ſiſters, and other relations, is there in continual habit—That on theſe mild and ten-

* "Leotychides interrogatus, quid potiſſimum oportet pueros ingenuos diſcere! Quæ illis, inquit, ubi ad virilem ætatem pervenerint, uſui ſunt futura." Cicero.

der charities of life, the temper, and the comfort of mankind chiefly depend—And, that, in a public ſchool, theſe amiable ſcions of the ſoul have not room to ſhoot, but muſt, of neceſſity, be miſerably neglected."

If to this argument it be anſwered, "That in a PUBLIC education there will be partialities and attachments formed:" it may be replied, "That theſe are not of exactly the ſame nature, nor will they have the ſame influence, on future temper and future happineſs."

It will, perhaps, be ſaid, "That in larger ſchools, connections and friendſhips may be formed, which may be of the moſt laſting, honourable, and advantageous tendency in future life."

This advantage appears to me to be a very precarious one. Early connections between a richer and a poorer boy, founded, probably, on caprice on the one hand, and abject obſequiouſneſs on the other, ſeldom continue long. Sometimes indeed an honourable union of equals may lay a foundation for future friendſhip, of the moſt endeared and permanent nature. And it is poſſible, that ſome inſtances may have occurred, of friendſhips formed, between youths whoſe fortunes were unequal, which have been as beneficial to the one, as honourable to the other. But, as boys are often ſeparated at ſo early an age, and diſperſed into ſuch different ſcenes and

regions,

regions, the hope of this ought not to be allowed much weight. And fact will, I persuade myself, bear witness to very few instances of this kind; too few, to give any great degree of force to this argument.

IV. SELF-GOVERNMENT.

By this term is meant, "The habit which, the friends of PUBLIC EDUCATION say, a boy early forms, in a large school, of conducting himself, of managing his own concerns, and of preparing himself for a steady, independent, manly line of action in future life. Such a school they describe as, "a miniature of the great world." And in this microcosm a boy is inured, to make his own way, to stand upon his own merit, to exert his own understanding and address, to maintain his own cause and his own consequence, to fight his own battle, to vindicate his own wrong, and to depend upon his own conduct and character, for the behaviour he meets with. In this society, it is said, all distinctions are levelled. The son of a nobleman appears as an equal to the son of a peasant. Insignificance, ill-temper, folly selfishness, together with the common vices of children (the seeds of similar and stronger vices in men) are discountenanced and discouraged, when they are sure to meet with contempt and hatred. And here, those public spirited and manly virtues grow best, which only can secure the general honour and approbation."

It

It is poffible, that fomething muft be deducted from this flattering reprefentation. In thefe little republics, fome active and bolder fpirits, diftinguifhed, probably, for ftrength and daring, rather than for morals, or literary excellence, gain an afcendancy over the reft. The other boys act under them, in fervile fubmiffion to their mandate, carry their burdens, fight their battles, and avenge their quarrels. Hence are learnt habits of fawning and fervility. Obedience muft be unreferved, under penalty of fevere chaftifement for rebellion. To crouch, in order to obtain the good graces of one of thefe leaders of a clan, will probably be the policy of a younger, and more timid boy. And he will obtain notice and protection, only by flattery, or fubmiffion the moft humiliating. The confequence often is, that when he himfelf rifes up to that degree of ftrength, which enables him to affert his own confequence, he practifes all the arts affumed by his former tyrant. And thus, a fyftem of vaffalage is handed down, from generation to generation. May it not be faid, that all this is as likely to produce abjectnefs of mind as independence; and turbulence, as proper fubordination?

V. MORALS.

The *greateft* object of education is, undoubtedly, to infpire the love of goodnefs. But here, the argument

argument ſeems very greatly to preponderate againſt the plan of public ſchools. And yet to this point, as to the all-animating center, ſhould every thing elſe be directed, and, by its tendency to this, ſhould every ſcheme be eſtimated. It would be a dreadful bargain, to give up morals for learning, or for any other accompliſhment.*

It cannot be denied, that there is certainly far greater danger of moral infection in a larger, than in a ſmaller number of boys. A ſingle boy may corrupt many, and diſſeminate a poiſon, of the moſt rank and baneful influence. It is impoſſible, where the numbers are ſo large, to give that minute and watchful attention to the diſcipline of the paſſions, and to the formation of the heart, which is ſo unſpeakably neceſſary in a good education. Boys, of a depraved turn of mind, have often an unlucky kind of wit, a ſomething in their *manner*, which enables them to do irreparable miſchief.

It is acknowledged, by a very ingenious and able advocate for public ſchools, † that the argument from morals lies undeniably againſt them. But this effect he aſcribes—to the neglect of education at home, before they

* "Nos liberalibus ſtudiis et diſciplines filios erudimus; non quia virtutem dare poſſunt; ſed quia animum ad accipiendam virtutem præparant." Cic.

† Knox.

come

come to ſchool—and to the general diſſipation of the age, to which even ſchools themſelves, which ought to be the nurſeries of better principles and better manners, too frequently accommodate themſelves.

If the fact be granted, that morals are in greater danger in a public, than a private ſchool, this will be, with many parents, a concluſive argument. Boys too ſoon, too eaſily receive the alarming contagion. And, when it is once received, it contaminates the whole maſs of the ſoul, and ſpreads its deadly poiſon through every future ſtage of life.

It is however, contended, "That boys, immured within the precincts of a private family, are often but ill prepared to ſtand the ſhock of future temptation; that they frequently ruſh, from the extreme of confinement, to the extreme of diſſipation, or diſſoluteneſs; and thus, atone for former reſtraint, by future extravagance."

This may have been the caſe, where the confinement has been impolitic, or exceſſive. But, as this is not neceſſarily attendant upon the private plan, it cannot be admitted as an univerſal argument againſt it.

It is to be regretted, that ſchools, in general, of almoſt every deſcription, pay ſo little attention to the culture of the heart; though this is, in compariſon with all others, an object, ſo infinitely ſuperior, that no embelliſhments

of

of ſcience, no advantages whatever, of any other kind, deſerve a moment's regard, without it.

And it is, perhaps, equally to be regretted, that ſo few parents are proper to have the ſole direction and management of their own children. *

It is far more eaſy to form the theoretic idea of a ſchool, which you might call "THE SCHOOL OF VIRTUE AND OF SCIENCE," than to realize it in action. And yet, I fear, that many parents would not approve of even *this ſchool*, if it were not likewiſe, "THE SCHOOL OF SHEWY ACCOMPLISHMENTS," which, with many, are of far greater moment, than virtuous excellence.

The MIDDLE PLAN, which we have already mentioned, ſeems calculated to blend, in ſome degree, the advantages, and to divide the diſadvantages, of both the others. By enlarging a private ſchool, ſo as more nearly to approach a public one, you ſecure every deſirable advantage for emulation. And, by having no more, than can be under the continual inſpection and management of the maſter, you provide for that particular and conſtant attention to every in-

* The ſaying of Philip upon the birth of his ſon Alexander, pays a high compliment to the philoſopher; but Ariſtotle himſelf could not *command* ſucceſs. His pupil does not ſeem to have fully anſwered to his tutor's care.

" Non tam gaudeo, quod natus eſt mihi filius, quam quod tempore Ariſtotelis natus eſt, cui tradatur erudiendus."

dividual,

dividual, which is abſolutely neceſſary to his beſt improvement.

But upon every plan, the whole will depend upon the ability, the induſtry, and I may add, particularly, upon the *manner* of the maſter, The advantages of the beſt plan may be loſt, by incapacity and negligence. And even the worſt may have a temporary brilliancy, from the ſuperior talents and attention of him who conducts it.

The nobleſt authority is that of love, mingled with reverence. Let us imagine, connected with real abilities, that indeſcribably happy *manner*, which we have already mentioned, but cannot explain. There will probably be an eaſy and willing empire, over pleaſed and unſuſpicious ſubjects. It will be an empire over the heart. Their ſubjection will be chearfully paid to one in whom they ſee, powers in their eye ſo amazing, connected with a temper ſo amiable, with manners ſo awfully engaging, with affections ſo ſincere, and with a treatment ſo generous, manly, and conſiſtent.

But, if we recollect a moment the exceedingly difficult points, to which education ſhould be directed, we ſhall perhaps rather wiſh, than expect, to ſee any ſcheme, in which they may be all accompliſhed. To keep up the continual impreſſion of reverence, without intimidating— to reſtrain the ſpirits, without depreſſing them—

to

to inſpire courage, without turbulence—vivacity, without forwardneſs—and diffidence, without dejection—to adminiſter praiſe, without puffing up—correction, without exaſperating—and ſteady diſcipline, without enfeebling the mind in its beſt energies.—Theſe are ſome of the grand objects of education.

Who, that conſiders the *difficulties* of this work, the various diſpoſitions, capacities, and nurſery-educations of boys; and the different tempers, views, and talents of parents and maſters, will not be ready to make every candid allowance for imperfection? And yet, who, that conſiders ITS INFINITE IMPORTANCE, will not wiſh every poſſible imperfection to be done away?

And who will not be ready to exclaim, with the philoſopher,

"Quid munus reipublicæ MAJUS MELIUSVE afferre poſſimus, quam ſi docemus atque erudimus Juventutem?"

Cicero.

A PLAN

A Plan *for the* improvement *and* extension *of* Liberal Education *in* Manchester. *By* Thomas Barnes, D. D. *Read April* 9, 1783.

IT is to the honour of the prefent age, that it has extended the empire of Science, and of the Arts, fo far beyond its antient boundary. The fpirit of Literary enterprize has gone forth, and has already won large domains from the regions of darknefs. It would be matter of wonder, and of lamentation, if, in a period fo diftinguifhed, *education*, which holds fo high a rank both as a fcience, and an art, fhould not have received fome fhare of the general improvement. But who will deny, that much has been already done, to render the benefits of liberal culture more diffufive, and more fuccefsful? Much as we lament, that the object and aim of many parents fhould be fo low; much as we defpife many of thofe frivolous embellifhments, which are efteemed the grace and finifhing of modern—modifh—education, ftill we muft acknowledge with pleafure, that confiderable advances have been made, and that young perfons now enjoy many affiftances in mental cultivation, unknown to their progenitors. The general fentiment,

of

of the influence and moment of ſuperior education, is now almoſt univerſally adopted. And nothing, we are confident, is neceſſary, but to produce a well-conceived and uſeful ſcheme, in order to ſecure the moſt honourable patronage, and the moſt liberal encouragement.

There yet remains ONE DESIDERATUM in Education, which many parents would be happy to ſee ſupplied, upon an unexceptionable plan. The ſtage which paſſes between a SCHOOL, and BUSINESS, is often a very diſtreſſing one to a parent, and an uſeleſs, if not a dangerous one, to a young man. He has paſſed through the common forms of Claſſical Inſtitution. He is rather too old, to continue to pace round the beaten track of a grammar ſchool; and yet he is too young, to be truſted abroad in the world, as his own maſter. Add to this, that his education, thus far, has been too confined and imperfect, to anſwer its nobleſt ends, of giving a true enlargement and direction to his ideas, and of producing a proper taſte for general and important ſcience.

What ſhall be done to fill up this awkward, and yet unſpeakably intereſting, chaſm of life? —It is beyond meaſure deſirable, that it might be filled up with the purſuit of knowledge, in ſome line, ſo as to aſſiſt and adorn all his future progreſs.

Every reſpectable tradeſman muſt have in his view the idea, of ſometime retiring from, or at

 leaſt

leaſt of leſſening, the multiplicity of cares and attentions which now preſs upon him. The decline of life ſeems to call for reſpite and conſolation. But how ſhall this receſs from buſineſs be ſupported, without ſome taſte for letters? I cannot figure to myſelf a more miſerable ſituation, than that of one, who retires from the hurry of the world, yet has no furniture of mind, to grace or to ſweeten his retirement? Unqualified for every liberal and ſuperior entertainment, he will probably ſink down, into languor —intoxication—and lethargy.

It is the natural, the laudable wiſh, of every parent, whom the bleſſing of Providence has raiſed to any degree of affluence, that his ſon may appear in the world, with character and accompliſhments, worthy of the reſpectable line, into which his father's fortune may introduce him. Mere money, without knowledge or virtue, is contemptible and miſchievous, in exact proportion to its amount. He muſt have amuſements and companions. But theſe will be of the loweſt, and moſt degrading caſt. His money, however, *he* will deem ſufficient to give him ſelf-conſequence. With flatterers, with the mob, it *may*. But, deſtitute of the beſt poſſeſſions, he will be an object of contempt, to all men of ſenſe—and of compaſſion, to every man of humanity and ſeriouſneſs.

Without

Without throwing the moſt diſtant reflection upon that plan of claſſical education, which generally, and, in my idea, very properly obtains at our common ſchools, no one will imagine, that the knowledge there acquired is ſufficient to improve and adorn the mind, in all its future ſtages. Such knowledge muſt be ſcanty, and undigeſted. There will be ſome ſhining particles, probably mixed with a large quantity of alloy. Language is merely the ſcaffolding of ſcience. The ſhreds and fragments of ſentiment, which a boy picks up, in conning over the Latin and Greek authors, are not ſurely deſerving of the name, of regular and ſyſtematic ſcience. And yet, without ſomething of ſyſtem and regularity, ideas float in the head in unformed maſſes, without method, or arrangement.

The boy, who excels in one branch, the knowledge of languages, may appear manly. The man, who has gained no more, muſt appear a boy. He that does not add general ſcience to profeſſional knowledge, is a mere pedant. And he who has not looked abroad from the Greek and Roman claſſics into the other branches of a poliſhed and extenſive education, knows but little of what is either moſt truly ornamental or uſeful. But WHERE ſhall that higher and more finiſhed knowledge be obtained?

Here a boy muſt ſtop ſhort—When, from names and words, he ſhould riſe to THINGS, he

is plunged immediately into the vortex of buſi-neſs—and from that moment, almoſt the whole of what he had been ſo many years in learning, is forgotten. At leaſt, little remains, but the withered ſcraps of knowledge, gleaned in his ſchool. All the ſcience which a boy of an ingenuous turn acquires, AFTER THIS, muſt be acquired without aſſiſtance. He has no precep-tor to direct him; he has no regular ſyſtem to purſue; his walks into the different ranges of literature muſt be deſultory, ſolitary, and un-comfortable.

For, WHERE ſhall this knowledge, or this taſte be obtained?—In a college, or univerſity?—But there, the expence deters: the danger terrifies. Numbers of young men, many of them irregularly educated, fluſhed with money, with conſequence, with paſſions, too often corrupt one another, and induce fatal habits of extravagance, diſſipation, and indolence—habits, entirely inconſiſtent with the ſobriety, frugality, and attention neceſſary to future ſucceſs and reputation, in any line of life—and above all, in BUSINESS.

Hence it is, that ſo very few of thoſe young men, who are deſtined for trade, enjoy any advantages beyond thoſe of a grammar ſchool.

It is granted, that the examples are too rare, of thoſe who have united, the manners of the Gentleman, the taſte of the Scholar, and the induſtry

induſtry of the Tradeſman. Yet ſuch examples *have* been ſeen, and may *ſtill* be ſeen among us. For who will ſay, that they are incompatible? or who would not wiſh that his ſon might exhibit ſo fair, ſo amiable an aſſemblage of excellence? Perhaps, one reaſon why they are ſo uncommon may have been, that thoſe places of education, which tend to form the Gentleman and the Scholar, have been unfriendly to the habits neceſſary to the Tradeſman; whilſt the warehouſe, in which the Tradeſman receives his mercantile mould, is, perhaps, equally unfavourable to ſuperior ornaments. But would it not be poſſible, that the advantages of both ſhould be combined together? In the houſe of a parent, or reſpectable maſter, and amidſt general habits of buſineſs, a young man, who ſhould continue to devote ſome part of his time to ſtudy, would not be ſo much refined, as to be unfit for commerce. And, perhaps, the happy art might be learned, of CONNECTING TOGETHER, LIBERAL SCIENCE and COMMERCIAL INDUSTRY. If the ſcheme appears viſionary, yet it deſerves a trial. It is, indeed, as far as I know NEW. I have never heard of a ſimilar eſtabliſhment. But it might eaſily be dropped, as ſoon as it appeared not to anſwer the ends of its inſtitution.

A plan of this nature, in a large town, it does not appear to me difficult to form, or to execute,

 if

if there were a general conviction of its utility, and a proper encouragement for undertaking it. This course of study should not, I think, be a mere continuation of that of a school; but, the application of school learning to superior objects. Those objects would probably be, *Natural Philosophy*, the *Belles Lettres*, and *Mathematics*; together with some attention to *History*, *Law*, *Commerce*, and *Ethics*. There are Gentlemen in this town, sufficiently eminent in these various departments of science, to lecture upon them with reputation and success. One part of a COLLEGE plan must indeed be dropped—that of living together in common apartments. But, probably, the omission of this would not be deemed a loss, by those, who know the temptations which often attend it. All the advantages of literary improvement might be here enjoyed.

A very important part of the plan would be, A course of lectures upon NATURAL PHILOSOPHY, in its extended sense, which should pay a very particular attention to CHEMISTRY, and MECHANICS, because of their intimate connection with our manufactures.

In addition to these, Courses of lectures upon HISTORY, COMMERCE, JURISPRUDENCE, CRITICISM, and ETHICS, together with the whole range of the BELLES LETTRES might, I persuade myself, be of essential service.

If with theſe were combined, ſome continued attention to LANGUAGES, antient and modern—and to MATHEMATICS—the ſcheme would be filled up, in a manner highly reſpectable and uſeful.

Some eſtabliſhment of this nature ſeems wanting, to compleat the many advantages for education, which are already enjoyed among us. Perhaps, few places can boaſt of greater advantages for the education of boys, in the firſt rudiments of ſchool learning. Our more public and more private ſchools have juſtly obtained a very conſiderable celebrity, not only at home, but abroad. If, to ſo fair a foundation could be added a ſuperſtructure equally excellent, the whole edifice would appear compleat, ſtrong, and noble.

A ſcheme like that we are now ſketching, might ſerve as a very agreeable preparation for thoſe, who are deſigned for the LEARNED PROFESSIONS by opening their way to thoſe more profound and ſyſtematical inſtructions, which they would afterwards receive, in our more public and celebrated inſtitutions. And, to thoſe Gentlemen deſigned for the COMMERCIAL line, it would be abundantly ſufficient, in order to give that general inſight into ſcience, which might anſwer the nobleſt purpoſes of mental cultivation.

We have already mentioned, the intermediate ſtage, between a ſchool and buſineſs, as often an

 uſeleſs

ufelefs, if not a dangerous one for youth. And yet, who would fcruple to fay, that more depends upon this period, as to the formation of manners, of habit, and of future character, than perhaps upon any other part of life, of equal duration? In this period, from fourteen to feventeen or eighteen years of age, the tranfition is made from boyifhnefs to manhood. The company, the tafte, the plan of future life are now generally eftablifhed. In this fpring, you behold the bloffoms; you prognofticate the fruit. A boy, before the age of fourteen, very feldom fees the end towards which he is going. After that age, he begins to obferve the point he fhould aim at: and not unfrequently, he gets more of real knowledge, and of the proper bent and direction of the mind, in two or three years after that period, than in all that have preceded it.

But what fhall a young man do, during this important interval? Shall he ftay at home? But here, probably, is no object before him, to fix, to entertain, or to improve his mind. He is in danger, therefore, of falling into liftleffnefs, and languor; of flying from this inactivity, fo irkfome to the fprightlinefs of youth, into improper and dangerous connections; or of feeking for amufement in gay company, the confequence of which is, diffipation and ruin. Hence, the trembling parent often finds himfelf obliged to fend his fon abroad into the world, though ever fo

desirous to keep him longer under his own eye, because he is sensible, he is losing time, and in danger of contracting habits of indolence, or of vice.

And even after a young man is engaged in business, there are many long evenings, and many hours of avocation, which might be usefully and agreeably filled up. Shall all the labour of so many years, as have been spent at school, be lost, and buried in everlasting oblivion? Shall so much pains have been taken, in laying a foundation, and in erecting scaffoldings, and shall the mind never rise from thence, to the higher regions of literary improvement? Shall a boy close his school books, and, from that moment, never open them again? Shall he bid farewel to study, and condemn the labour and difficulty, which he underwent in the stage of youth, merely because he has not learned to *apply* the knowledge he there gained, to its noblest end?

It is indeed argued, by some, "That science and business are incompatible; and that a taste for the *one*, almost necessarily disqualifies a man for succeeding in the *other*." But surely a taste for knowledge is not half so detrimental, as that rage for pleasure, which so universally, and almost necessarily prevails, where a better relish has not previously been formed. Would not a taste for manly knowledge be a noble antidote against the

the allurement of corrupting pleafures? Would a young man be in fo much danger of being drawn afide into conviviality, or fafhionable amufements, if he had a rational and agreeable entertainment at home; if he could retire from his warehoufe, and relieve his jaded fpirits by fome animating ftudy, and thus fet a finer edge upon his mind again, blunted and worn down by intenfe application?

It is plain, that many of our tradefmen, the moft induftrious and fuccefsful, have many hours of avocation Human nature could not endure a perpetual fcrew to bufinefs, without relaxation. Might not thefe hours be often filled up much better, more honourably more ufefully, more happily, than they commonly are? Would mental cultivation, to a certain point, interfere with the neceffary demands of bufinefs? I know, it is generally thought fo. But it is true in fact? Shall we be told, "That moft of our eminent tradefmen rofe from low beginnings by unremitting induftry, whilft thofe, who fet out with fairer fortune and profpects, made comparatively little progrefs?" But is not the reafon of this, that our young men, inftead of forming a manly and cultivated tafte, fell into company and habits, which effectually diffipated their minds, and unfitted them for proper attention to any important object whatever?

But,

But, "There have been young men too bookiſh for a warehouſe"—It is granted. But it is probable, they never had a proper turn of mind for buſineſs. Their parts were wrong caſt. They ſhould have been brought up to ſome liberal profeſſion, more agreeable to their genius. They were probably obliged to enter upon a line of life not correſpondent to their ruling paſſion. No wonder, they did not ſucceed!

The object to be aimed at is, To give a boy, in theſe intermediate years, to which alone our plan extends, that degree of knowledge and of taſte, which may make him more than the MERE MAN OF BUSINESS in future life. The point to be avoided is, The giving him views, habits, and taſte, which may be UNSUITABLE FOR A MAN OF BUSINESS, and which he would have to unlearn again, when he came to ſettle down to the regular *routine* of a warehouſe.

How far it would be poſſible to gain this advantage, and to avoid this diſadvantage, is a point of the utmoſt concern to determine. Might not a boy, for ſome years after he has been introduced into buſineſs, have ſome intervals allowed him, which might be ſufficient for the cultivation of his mind? Is it neceſſary that, the moment he enters a warehouſe, he ſhould lay down this maxim—"I muſt now give every moment to trade—I muſt have but ONE object

objćt—I muſt give up books, knowledge—and every thought but ONE, that of getting money?"

And even admitting, that there were ſome competition, ſuch as is aſſerted, between literature and merchandize; if the plan we are recommending ſhould in any degree interfere with an unremitting and exceſſive attachment to buſineſs—is it neceſſary that buſineſs ſhall be followed upon this ſlaviſh and degrading plan, to the excluſion of every idea, but that of gain? Might not ſomething be abated of this over-plodding diligence, and yet the mind, even granting ſome diminution of fortune, be, upon the whole, an unſpeakable gainer?

It would certainly be a high honour, as well as an unſpeakable advantage, to this riſing and opulent town, to have within itſelf an Inſtitution which would proclaim its taſte, as well as its affluence. It would be a laudable ambition, to aſpire after a literary, in addition to that mercantile reputation, by which it is already ſo greatly diſtinguiſhed.

The SOCIETY to which I have now the honour of addreſſing myſelf, has added no ſmall degree of reſpectability, in the eyes of our fellow-countrymen, and even of foreigners. They have ſeen, with pleaſure, a ſet of Gentlemen riſe up, in the midſt of a place devoted to commerce as the friends of LITERARY and PHILOSOPHIC excellence. An inſtitution, ſuch as I am now recommending, would ſtrengthen that favourable impreſſion,

impreſſion, by declaring to the world, that increaſing wealth is accompanied with its rare, but honourable attendant, increaſing wiſdom—and, that thoſe, whoſe ſagacity and induſtry have been able to extend the manufactures, are equally deſirous of extending the beſt improvement and embelliſhment, of their country. It would contradict the diſgraceful idea, that a ſpirit of merchandize is incompatible with liberal ſentiment, and that it only tends to contract and vulgariſe the mind.

But, Gentlemen, in order to the ſucceſs of this plan, it is neceſſary, that it come before the public UNDER YOUR PATRONAGE AND PROTECTION. —That theſe imperfect outlines be improved and filled up by your matureſt deliberations—That different Gentlemen ſhall engage in different departments—And that the ſcheme be proſecuted with vigour, with harmony, and with perſeverance.

Under ſuch a ſanction, and with ſuch advantages, it could not fail of ſucceſs. Perhaps it might become, in the courſe of years, like a rill, ſwelled in its progreſs by ſucceſſive tributary ſtreams, a noble torrent, and enrich, and adorn the country all around,

N. B. *The Scheme here recommended being approved, and patroniſed by the* SOCIETY, *the following Paper was, at their deſire, drawn up by the Rev. Dr.* BARNES, *and circulated, with the annexed teſtimonial from the* PRESIDENTS.

RESOLVED,

MANCHESTER, APRIL 23, 1783.

RESOLVED, *at a Meeting of the* LITERARY *and* PHILOSOPHICAL SOCIETY—*That the following Paper, drawn up by a Member, at the Requeft of the Society, be printed, and offered to the Confideration of the Public.*

JAMES MASSEY, THOMAS PERCIVAL, PRESIDENTS

PROPOSALS *for* ESTABLISHING *in* MANCHESTER *a* PLAN OF LIBERAL EDUCATION, *for* YOUNG MEN *defigned for* CIVIL *and* ACTIVE LIFE, *whether in* TRADE, *or in any of the* PROFESSIONS.

THERE is no fubject, except RELIGION, in which every perfon is more deeply interefted, both as an individual, and as a member of fociety, than in EDUCATION. And it is to the honour of the prefent age, that it encourages, with diftinguifhed generofity, every well-planned fcheme, the object of which is, to improve the fyftem of education, and to extend its beneficial influences.

In few places has this liberal fpirit appeared, of late, more confpicuoufly, than in MANCHESTER. There are, indeed, few places, which have enjoyed

enjoyed the advantages of *early tuition*, in a more eminent degree. Our *public* and *private* ſchools have juſtly obtained a very conſiderable celebrity, both at home and abroad.

There is, however, in the opinion of many intelligent perſons, deeply intereſted in the ſubject, ſomething eſſential ſtill wanting among us, to compleat the courſe of education, for active and commercial life. In their judgment, a period ſubſiſts, in the life of a young man deſigned for trade, which it is not eaſy to fill up in the moſt advantageous manner. The want of a happy tranſition from a grammar ſchool to buſineſs, by ſome mode of more general and manly inſtruction, ſuited to that intermediate ſtage, has been ſenſibly felt, as a *deſideratum* of unſpeakable importance. At preſent, there is hardly any *middle line* of education, between that, of a ſchool for the elements of language and accompts, and that, of a college—the latter of which ſeems better adapted for a profeſſional man, than for one deſigned for commerce. It is ſurely deſirable, that he ſhall *now* riſe, from words to things, from Language to ſentiment. All that he has yet been doing, is only preparatory to real knowledge. Language, of itſelf, is but a ſcaffolding to ſcience. And ſhall the labour of ſo many years be now loſt and forgotten, as it too commonly is, when a young man leaves the ſchool, and enters upon life? Or, ſhall the gleanings of mixed

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and cafual fentiment, collected from a few *Greek* or *Roman Claffics*, conftitute all the knowledge, which is to adorn and fweeten the remainder of his days? Might not, then, this period be filled up with great advantage, in the acquifition of SUPERIOR SCIENCE, if there were the opportunity at hand, of fome well-digefted and unexceptionable plan?

Probably, in thefe intermediate years, the tafte, the habits, and the whole character of a youth, may receive indelible impreffions. From *thefe years* we are to date, his honour, his infignificance, or his infamy—his fuccefs, or his ruin. Of what infinite importance is it, then, that this interefting period be cultivated with the utmoft diligence, and fown with every feed, capable of producing real happinefs or ornament, in future life!

But there are fome, who deny, that any fuch intermediate ftage, as we have here fuppofed, *does*, that is, *ought to* exift. They contend, that a boy fhould be fet down, *as foon as poffible*, to active and conftant bufinefs, in order to obtain, by early initiation, all the habits of induftry and attention, neceffary to future fuccefs.—Such Gentlemen will not furely fay, That what a youth has acquired at fourteen years of age, fuppofing him to have made ever fo great a proficiency in fchool learning, is fufficient to conftitute the whole of his mental furniture hereafter!—Or, that

that any higher degrees of liberal ſcience are incompatible with buſineſs! A ſeverer libel upon trade could not poſſibly be uttered! If it were *true*, who would not wiſh to abate a little of the qualifications of the mere tradeſman, in order to enjoy the more reſpectable ornaments, of knowledge, and mental cultivation?—But there are many examples in MANCHESTER—and we point to them with pride and pleaſure,—of the union of a taſte for literature, with every neceſſary and deſirable requiſite for active and ſucceſsful commerce. Who does not wiſh to ſee the number of *ſuch characters* multiplied among us? Who would not rejoice, *thus* to confute that degrading maxim, that commerce only ſerves to enfeeble and contract the nobleſt powers of the human mind *

But,

* In the Memoirs of Albert de Haller, M. D. lately publiſhed by Mr. Henry, we are told, page 119, "That he laid a plan for a ſchool, deſigned for the education of the opulent citizens; where they might be qualified to fill the principal offices of the republic, and might be inſtructed, not ſo much in thoſe points, which the grammarians of the ſeventeenth century eſteemed the moſt eſſential branches of education, as in thoſe, which the philoſophers and men of learning of the preſent age have judged to be eſſential to the intereſts of humanity."—This was at BERNE, a place ſupported by arts, manufactures, and commerce.

In the inſtructions lately iſſued from the Lord Lieutenant of Ireland, to the Earl of Tyrone, &c. to conſult

But, let us imagine a young man, engaging in bufinefs, at fourteen or fifteen years of age: There muft occur, for a few years at leaft, many hours of relaxation, which might be ufefully and agreeably employed. If the duties of the warehoufe employ the *day*, a part of the long winter *evenings* might be fpent, in a more rational and improving manner, than they too commonly *are*—than they neceffarily *muft be*, if there be

upon a plan for accommodating the GENEVANS, who are coming to fettle in Ireland, is the following paragraph: "And whereas young perfons of rank and fortune, from all parts of Europe, reforted to the city of Geneva, to profit from the fyftem of education eftablifhed there, under profeffors of eminence in ufeful and liberal ftudies and accomplifhments; and whereas a School or Academy formed upon the fame principles in this kingdom, would forward his Majefty's gracious difpofitions for the encouragement of religion, virtue, and fcience, by improving the education and early habits of youth, and would remove the inducements to a foreign education; and, being conducted with that attention to morality and virtue, which hath diftinguifhed the eftablifhments in that city, may attract foreigners to refide in this kingdom for the like purpofe: we do further pray and empower you, to confider and digeft a plan for a School and Academy of education, to be eftablifhed in the new colony, and to make a part of the conftitution thereof, under fuch inftitutions and regulations, and with fuch privileges, as may beft contribute to the ends hereby propofed."—At GENEVA, arts and manufactures flourifh in the higheft degree, befriended and affifted by the SCIENCES.

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not ſome taſte for literary entertainment. Amuſement is neceſſary to young men. If this be not enjoyed *at home*, and *within themſelves*, they will fly abroad into company, and ſeek it, in taverns, in conviviality, and diſſipation. Hence, they will form habits, of all others the moſt unfavourable to ſucceſs in buſineſs, and againſt which, a reliſh for manly ſcience would have been, next to religion, the nobleſt antidote. Let the liſt of bankrupts be examined—For *one*, who has fallen, a ſacrifice to literature and refinement, it would be eaſy to point out *a hundred*, who have fallen, for want of that rational, domeſtic, and delightful entertainment, which a proper taſte for knowledge would have afforded them.

Few young men are admitted to *manage* a buſineſs, till they are, at leaſt, eighteen years of age. Before this age, they would not, probably, have prudence or ſteadineſs, to deſerve ſo great a confidence! Till *then*, their intervals of leiſure give them a perfect remiſſion from care. The improvement of their minds, in theſe intervals, if not carried beyond a certain point, would not interfere with mercantile accompliſhments. It would afford a grateful receſs, from the buſtle and attention of buſineſs. It would hereafter give a man the *habit*, and the *means*, of filling up whatever leiſure he may command, in a moſt agreeable manner. It would give him

respectability and consequence, even upon the exchange. And it would chear his retirement, if, in the evening of life, he should wish to decline, or diminish, the multiplicity of cares, which now press upon him.

But *where*, in the present state of things among us, shall this mental cultivation be obtained? We have no regular established means, for such an acquisition. There are some young men, surely not the least respectable among us, who are, with a laudable ambition, endeavouring to glean such instruction, by their own solitary and desultory efforts. For want of proper assistance, their progress is necessarily slow, embarrassed and uncomfortable. They lose much valuable time. And, after all, the knowledge they *do* acquire, wants much of that precision and arrangement, which can, in general, only be attained by regular and systematic study.

It is therefore proposed, to ESTABLISH in MANCHESTER, a SEMINARY OF LIBERAL SCIENCE, the object of which shall be, to give a young man some taste for SUPERIOR KNOWLEDGE, to provide him with a domestic, constant, internal source of entertainment, and thus to improve his morals, his piety, and his happiness—*at the same time*, that he is forming early habits of commercial industry. The design of this plan is, to *connect* the *one* of these, with the *other*—

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the improvement of the *mind*, with the proper attentions to *business*. This union, of mercantile and mental accomplishments, is certainly of unspeakable importance to those, whose fortunes and prospects destine them to move in the higher spheres of life. The respectable and superior tradesman may be allowed to have his mind well furnished, and his sensibilities refined, without injury—nay, with very great advantage, even to his trade itself. By means of superior education, he will be enabled to appear in the world, in that line, to which an honourable ambition should prompt him to aspire. His connections will be more advantageous. To his customers, to his friends, to his fellow-citizens, to foreigners, to the world in general, he will appear with greater consequence and respectability. His advice, his example, his influence, will have a weight, which *mere fortune*, without mental cultivation, can never, of itself, command.

It is further proposed, That several Gentlemen shall unite together, in delivering a course of liberal instruction, in LANGUAGES, the BELLES LETTRES, HISTORY, COMMERCE, LAW, ETHICS, NATURAL PHILOSOPHY, CHEMISTRY, and MATHEMATICS.

In this institution, every narrow principle ought to be rejected. A plan, formed for public utility, should be generous and enlarged, so

as to extend itfelf as widely as poffible, for the common intereft. Science and Arts are of no political or religious party. They tend, in the happieft manner, to deftroy thofe little prejudices, which alienate one man from another. By opening the foul to wider aims, they improve our charity, our morals, our chriftianity—and, by neceffary confequence, exalt our trueft happinefs.

At prefent, we can only fketch a *rude* and *general outline* of the fcheme now in contemplation.

The LEARNED LANGUAGES form fo important a part of LIBERAL EDUCATION, that it is not neceffary to enlarge on the propriety of continuing and increafing an acquaintance with them. This it is propofed to do, by lectures, upon a popular and entertaining plan, which fhall connect occafional remarks, on the hiftory, mythology, philofophy, manners, jurifprudence, &c. of antient times, with the authors which fhall be read.

The BELLES LETTRES prefent a wide field for highly interefting and ufeful lectures upon *Criticifm*, *Poetry*, *Oratory*, and the *Polite Arts*. To this department may likewife be added, lectures upon GENERAL HISTORY, and particularly, upon the HISTORY of our own COUNTRY—upon COMMERCE—LAW—LOGIC—and MORALS. Thefe various fubjects open fo many views into human nature, as cannot fail of delighting the mind, and

and improving it in its beſt principles and operations.

Natural philosophy in all its branches, (except Chemiſtry)—including *Optics*, *Pneumatics*, *Hydroſtatics*, *Aſtronomy*, *Electricity*, &c.—or the diſcoveries relating to *Viſion*, *Air*, *Water*, the *Heavenly Bodies*, *Electric Fire*, &c —and attended with experiments, on *Microſcopes*, *Teleſcopes*, *Air-Pumps*, *Fire-Engines*, *Orreries*, *Electric Machines*, &c. will form a very large and important part of the propoſed plan.

Chemistry will be a province by itſelf. Its extent, and reference to ſo many of the *arts*, on which our *manufactures* depend, entitle it to this diſtinction. Here, will be conſidered, the elementary principles of *bodies*, the nature of *Fire*, *Air*, *Acids*, &c. And the whole will have a reference to the *arts* of *Dyeing*, *Bleaching*, &c. which, depending upon chemical principles, might probably, by the knowledge of thoſe principles, be very greatly extended and improved.

The mathematics, including *Geometry*, *Trigonometry*, *Conic Sections*, *Algebra*, &c. would ſufficiently fill another department, of the importance of which no detail is here neceſſary.

A scheme, thus filled up, would, we flatter ourſelves, comprize the principal objects, moſt deſirable in a seminary of liberal instruction. If, however, it ſhould be found proper to add to theſe, *other* branches of ſcience, ſuch

as NATURAL HISTORY, MODERN LANGUAGES, &c. &c. it is not doubted, but that Gentlemen, well qualified to lecture upon them, would concur in giving affiftance and perfection to a plan of fuch general utility and importance.

If, to provide a prefervative from thofe low, corrupting pleafures, by which thoufands of our young men are continually deftroyed—If, to extend ftill further the branches of our commerce, the finews of our wealth, by differminating thofe principles, on which the arts depend—If, to prepare an agreeable entertainment for every period of life, and an honourable character and confolation for its evening—If, to add refpectability to opulence, and dignity to human nature—If THESE are objects, worthy our firft regard, the Inftitution here propofed, appears to wear an afpect, friendly to human excellence and human happinefs, and to deferve the patronage of our fellow-citizens. The more it is confidered, the more, we truft, it will appear to merit their approbation and encouragement.

We have mentioned it, as *principally* accommodated to young men, defigned for a refpectable line of *trade*. But thofe, who are defigned for the different *profeffions*, as well as thofe, who have *no* particular profeffion in view, will, probably, find very confiderable advantage from it, either, as preparatory to the univerfity, or to life in general. And there are many Gentlemen, further advanced in age, who have fuffi-

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cient leiſure and diſpoſition for ſuch purſuits, to whom it would, poſſibly, be an agreeable circumſtance, to have the opportunity of ſpending two or three hours in a week, in ſo rational, and improving an entertainment.

Strongly impreſſed with theſe ideas, the Gentlemen who wiſh well to this ſcheme, hope to ſee it proſecuted with zeal and perſeverance. They conceive, that it will be an honour to the town of MANCHESTER, to have within itſelf ſuch an inſtitution, as that here propoſed, and to take the lead, among the other great towns of this opulent kingdom, in eſtabliſhing a plan, which, it is not improbable, many others will be ambitious to follow.

If, upon this *general view*, THIS INSTITUTION ſhould appear worthy of the attention and patronage of the PUBLIC, a more *particular* account of its *extent* and *objects* will be given, in another paper,—together with a diſtinct ſyllabus of the lectures propoſed to be delivered, in every ſeparate department. And, it is hoped, that its commencement may take place the enſuing winter.

N. B. It is propoſed, that the lectures ſhall be delivered in the EVENING, or, ſo as not to interfere with the regular hours of buſineſs.

It may not be improper to mention, that the scheme here proposed has been carried into execution with considerable success. During the two last winters, LECTURES *have been delivered,* IN DIFFERENT BRANCHES OF SCIENCE, *to numbers of Gentlemen, who have thus given the most respectable sanction to the undertaking. And it may be added, that the Gentlemen engaged in the office of* PRÆLECTORS, *animated with the encouragement they have already received, hope to pursue their important object with vigour and perseverance, not doubting but that they shall continue to enjoy the patronage and support of the friends of science and of virtue.*

As it is desirable that SIMILAR ESTABLISHMENTS *should be formed in* OTHER LARGE TOWNS, *it will not probably be amiss to subjoin the* FIRST REPORT *of this institution, printed* 1783.

COLLEGE OF ARTS AND SCIENCES,

INSTITUTED AT MANCHESTER, JUNE 6, 1783.

THIS INSTITUTION is intended to provide a course of LIBERAL INSTRUCTION, compatible with the engagements of commercial life, favourable to all its higher interests, and, at the same time, preparatory to the systematic studies of the UNIVERSITY. To unite *philosophy* with *art*, the moral and intellectual culture of the *mind*, with the pursuits of *fortune*, and to superadd the noblest powers of enjoyment to the acquisition of wealth, are the great objects which it professes to hold in view. The consistency of these objects has been fully ascertained; and their importance cannot be doubted. It only remains, therefore, to

to ſtate the particulars of the plan, which now claims the attention, and the ſupport of the public. And the GOVERNORS of the COLLEGE indulge the pleaſing, patriotic hope, that the following CONSTITUTIONS and REGULATIONS will enſure to their undertaking, permanency, reſpectability, and ſucceſs.

CONSTITUTIONS.

I. That the Lord LIEUTENANT of the County Palatine of LANCASTER, and the KNIGHTS of the SHIRE, be appointed PATRONS of the college, and requeſted to honour the inſtitution with the ſanction of their names and authority.

II. That a PRESIDENT, and EIGHT GOVERNORS be appointed, who, together with FOUR of the ſenior, or firſt nominated PRÆLECTORS, (not being GOVERNORS,) ſhall jointly tranſact all the buſineſs, and direct all the affairs of the inſtitution.

III. That the PRESIDENT, GOVERNORS, and PRÆLECTORS, ſhall hold their reſpective offices, *quamdiu ſe bene geſſerint*; and ſhall not be removeable, but by the votes of *two thirds* of the whole preſiding body.

IV. That the number of GOVERNORS ſhall not, hereafter, be changed, nor any election made, but to fill up the vacancies, which may at any time happen; and that ſuch election ſhall be made within *three months* after the vacancy.

V. As a mark of reſpect to the LITERARY AND PHILOSOPHICAL SOCIETY of MANCHESTER, which has ſo fully diſcuſſed the merits, and ſo zealouſly encouraged the plan of this inſtitution, that the preſent nine officers, viz. the PRESIDENTS, VICE-PRESIDENTS, SECRETARIES, and TREASURER, be appointed GOVERNORS of the college.

VI. That

VI. That *two meetings* of the *officers* and *prælectors*, of the college, ſhall be held *annually*, viz. on the laſt Thurſdays in the months of September and March.

VII. That the PRESIDENT, or any three GOVERNORS, be impowered to call a meeting of the OFFICERS and PRÆLECTORS, whenever, *he*, or *they*, ſhall judge it expedient or neceſſary.

REGULATIONS.

I. That all deciſions of the GOVERNORS aud PRÆLECTORS, if required, ſhall be by *ballot:* and, that a number leſs than *ſeven*, to be convened by a general ſummons, ſhall not be competent to tranſact buſineſs.

II. That Tueſday, Thurſday, Friday, and Saturday, be the *days* appointed for the lectures, in the enſuing ſeſſion: and that the *time* of lecturing be from about *ſix* to about *nine* o'clock in the *evening*, with the intermiſſion of about half an hour, or an hour.

III. That a lecture ſhall not, uſually, exceed *an hour:* and that no more than *two lectures* ſhall be delivered in the courſe of *one evening*.

IV. That it be recommended, that no more than *two lectures* be given by each PRÆLECTOR, *weekly*.

V. That the FEES to be paid ſhall not exceed TWO GUINEAS per ſeſſion, to each PRÆLECTOR, whoſe courſe is attended; and that no alteration ſhall be made in theſe terms, without the conſent of a majority of the GOVERNORS and PRÆLECTORS.

VI. That the ſubſequent ſeaſon of lecturing ſhall commence about the beginning of *October*, and end about the beginning of *April*.

VII. That no *free tickets* of admiſſion ſhall be given: but that the lectures ſhall be open to all the OFFICERS and PRÆLECTORS of the COLLEGE.

LECTURES

LECTURES *to be delivered the ensuing Session.*

I. On PRACTICAL MATHEMATICS—the principal branches of NATURAL and EXPERIMENTAL PHILOSOPHY—GEOGRAPHY—and the use of the GLOBES; by Mr. HENRY CLARKE *(This course was not delivered.)*

II. On CHEMISTRY, with a reference to ARTS and MANUFACTURES; by Mr. THOMAS HENRY, F. R. S.

III. On the THEORY and HISTORY of the FINE ARTS; by Mr. GEORGE BEW.

IV. On the *origin, history,* and *progress* of ARTS, MANUFACTURES, and commerce,—the COMMERCIAL LAWS and REGULATIONS of different COUNTRIES,—the nature of COMMUTATIVE JUSTICE; of OATHS, CONTRACTS, and other branches of COMMERCIAL ETHICS; by the Rev. THOMAS BARNES.

V. *A course of lectures on* MORAL PHILOSOPHY *was delivered,* BY THE SAME, *in* 1784.

OFFICERS OF THE COLLEGE.

PATRONS.

The Right Honourable the Earl of DERBY:
Lord Lieutenant, and Custos Rotulorum, of the County Palatine of LANCASTER.

Sir THOMAS EGERTON, Bart. } Knights of the Shire.
TOMAS STANLEY, Esq. }

PRESIDENT.

THOMAS PERCIVAL, M.D. F.R.S. & S. A. &c. &c.

GOVERNORS.

James Massey, Esq.	Charles White, Esq. F.R.S.
Rev. Thomas Barnes.	Mr. Thomas Henry, F.R.S.
Alexander Eason, M. D.	Mr. George Bew.
Rev. Samuel Hall, A. M.	Mr. Isaac Mosse.

The

The PRESIDENT and GOVERNORS of this COLLEGE are authorized to inform the public, that, whenever it may be deemed expedient to *extend* the plan, ſo as to render it a proper introduction to PROFESSIONAL STUDIES, in the UNIVERSITIES, Gentlemen of diſtinguiſhed merit, in *different departments* of ſcience, have promiſed to unite their labours, with thoſe of the PRÆLECTORS, who now engage in the undertaking. And they flatter themſelves, that, as this inſtitution diſclaims all relation to *parties*, either in *religion* or *politics*, and originates in the moſt generous and laudable views, it cannot fail to meet with candour, approbation, and encouragement. Many honourable teſtimonies, in its favour, have already been received, from the ableſt judges. And the GOVERNORS acknowledge, with peculiar ſatisfaction, the very obliging terms in which the Lord LIEUTENANT of the COUNTY, and the two KNIGHTS of the SHIRE, have been pleaſed to ſanction it with their patronage. "I ſhall be happy," ſays his Lordſhip, in a letter to the PRESIDENT, on this occaſion, "by every means in my power, to promote an undertaking, carried on upon ſuch liberal principles, and directed to ſuch a noble and beneficial object."

N. B. Thoſe, who wiſh to ſubſcribe to any courſe, or courſes of lectures, are deſired to deliver their names, *as ſoon as convenient*, to the preſident, or to ſome governor or prælector of the college.

MANCHESTER, *July* 9, 1783.

On ORICHALCUM. *By the Right Rev.* RICHARD WATSON, D. D. F. R. S. &c. &c. *Lord Bishop of* LANDAFF. *Communicated by Dr. Percival. Read October* 1, 1783.

WE have a proof, from the writings of *Cicero*, that the *Romans*, in his time, underſtood by the term *Orichalcum*, a metallic ſubſtance reſembling gold in colour, but very inferior to it in value. He puts the following caſe—" Whether, if a perſon ſhould offer a piece of *gold* to ſale, thinking that he was only diſpoſing of a piece of *Orichalcum*, an honeſt man ought to inform him that it was really gold, or might fairly buy for a penny what was worth a thouſand times as much."* It is not contended, that the argument, in this place, required any great accuracy in aſcertaining the relative values of gold and Orichalcum; yet we may reaſonably conclude from it, that orichalcum might by an ignorant perſon be miſtaken for gold, and, that it was but of ſmall eſtimation when compared with it.

Julius Cæſar robbed the Capitol of three thouſand pound weight of gold, and ſubſtituted as

* Cicer. de Off. L. III.

much

much gilded copper in its ſtead ; * in this ſpecies of ſacrilege, he was followed by *Vitellius*, who deſpoiled the temples of their gifts and ornaments, replacing the gold and ſilver by tin and Orichalcum. † From this circumſtance alſo, we may collect, that the Roman Orichalcum reſembled gold in colour, though it was far inferior to it in value.

It is probable, that the Orichalcum here ſpoken of was a metallic ſubſtance, greatly analogous to our braſs, if not wholly the ſame with it. The value of our braſs, is much leſs than that of gold, and the reſemblance of braſs to gold in colour, is obvious at firſt ſight. Both braſs and gold, indeed, are ſuſceptible of a variety of ſhades of yellow ; and, if very pale braſs be compared with gold, mixed with much copper, ſuch as the foreign goldſmiths, eſpecially, uſe in their toys, a diſparity may be ſeen ; but the nearneſs of the reſemblance is ſufficiently aſcertained in general, from obſerving that ſubſtances gilded with braſs, or, as it is commonly called, Dutch leaf, are not eaſily diſtinguiſhed from ſuch as are gilded with, gold leaf.

The *Romans* were not only in poſſeſſion of a metallic ſubſtance, called by them Orichalcum, and reſembling gold in colour, but they knew

* Suet. in Jul. Cæſ. C. LIV.

† Id. in Vitel. C. VI.

alſo

alſo the manner of making it, and the materials from which they made it, were the very ſame from which we make braſs. I am ſenſible, that in advancing this opinion, I differ from authors of great credit, who eſteem the art of making braſs to be wholly a modern invention. Thus M. *Cronſtadt* does not think it juſt to conclude from old coins and other antiquities, that it is evidently proved, that the making of braſs was known in the moſt ancient times;* and the authors of the French *Encyclopedie* aſſure us, that our braſs is a very recent invention. †

Pliny, ſpeaking of ſome copper which had been diſcovered near *Corduba* in the province of *Andaluſia* in *Spain*, ſays, "this of all the kinds of copper, the *Livian* excepted, abſorbs moſt *cadmia*, and imitates the goodneſs of *Aurichalcum*." ‡ The expreſſion, 'abſorbs moſt *cadmia*,' ſeems to indicate, that the copper was increaſed in bulk, or in weight, or in both, by means of the *cadmia*. Now it is well known, that any definite quantity of copper is greatly increaſed, both in bulk and in weight, when it is made into braſs by being

* Miner. p. 218.

† Art. Orichalque—"The veſſels here called brazen, after ancient authors, cannot have been of the materials our preſent braſs is compoſed of, the art of making it is a modern diſcovery." See Laughton's Hiſt. of Ancient Egypt. p. 58.

‡ Hiſt. Nat. L. XXXIV. S. 2.

fluxed

fluxed in conjunction with *calamine*. The other attribute of the copper when mixed with *cadmia*, was, its resembling *Aurichalcum*. We have seen from *Cicero*, that the term *Orichalcum* was applied to a substance far less valuable than gold, but similar to it in colour; and it is likely enough, that the *Romans* commonly called the mixture of copper and *cadmia* Orichalcum, though *Pliny* says, that it only resembled it; he, as a naturalist, speaking with precision, and distinguishing the real Orichalcum, which in his time, he says, was no where produced, from the factitious one, which, from its resemblance to it, had usurped its name.

Sextus Pompeius Festus abridged a work of *Verrius Flaccus*, a grammarian of considerable note in the time of *Augustus*. In this abridgement, he defines *cadmia*, to be an earth which is thrown upon copper, in order to change it into Orichalcum.* The age in which *Festus* flourished is not ascertained: he was unquestionably posterior to *Martial*, and some have thought that he lived under the Christian Emperors. But leaving that point to be settled by the critics, if he expressed himself in the words of the author, whose work he abridged, we have from him a decisive proof, that *cadmia* was considered as a species of earth,

* Cadmia-Terra quæ in æs conjicitur, ut fiat Orichalcum. Fes. de Ver. Seq.

and

and that the Romans ufed it for the converting of copper into a metallic fubftance, called, in the Auguftan age, Orichalcum.

In oppofition to this, it ought to be remarked, that fome underftand by the *cadmia* of *Pliny*, not calamine, but native arfenic. They feem to have been led into this opinion, from obferving that Pliny fays, *lapis ærofus* was called *cadmia*. For, apprehending that by *lapis ærofus* Pliny underftood a kind of ftone which caufed ulcers and erofions in the flefh of thofe who were occupied in working it, and knowing that arfenic produced fuch an effect, they have concluded that cadmia was native arfenic.* This, probably, is a miftake, arifing from a mifinterpretation of the word, *ærofus*. Pliny ufually, if not conftantly, applies that word to fubftances in which copper is contained, without having any refpect to the actions of fuch fubftances on the flefh of animals. Arfenic, moreover, when mixed with copper, does not give a gold, but a filver-like appearance to copper. And laftly, Pliny in another place exprefsly fays, that the ftone from which brafs was made was called cadmia; now it is impoffible to make either brafs or copper from arfenic.

* - - - - nous foupconnons que Pline a voulu defigner par Lapis ærofus, uni pierre qui mange et fait de ulceres ou èrofions a ceux qui la travaillent, et qui eit probablement l'arfenie vierge. Miner. par M. Vaimont de Bomare, V. II. p. 64.

Ambrose, bishop of *Milan* in the fourth century says, that copper, mixed with certain drugs, was kept fluxed in the furnace till it acquired the colour of gold, and that it was then called Aurichalcum.* *Primasius*, bishop of *Adrumetum* in *Africa*, in the sixth century, observes, that Aurichalcum was made from copper, brought to a golden colour by a long continued heat, and the admixture of a drug.† *Isidoras*, bishop of *Seville* in *Spain*, in the seventh century, describes Aurichalcum as possessing the splendour of gold, and the hardness of copper, and he uses the very words of Primasius respecting the manner of its being made.‡ The drug spoken of by these three bishops was probably *cadmia*. Prepared *cadmia* is highly commended by Pliny as useful in disorders of the eyes,‖ and it is still with us, under the more common appellation of *calamine*, in some repute for the same purpose. Hence, considering the testimonies of *Festus* and *Pliny* to the application of *cadmia* in making either

* Æs namq; in fournace, quibusdam medicaminibus admixtis, tamdiu conflatur, usq: dum colorem auri accipiat, et dicitur aurichalcum. Amb. in Apoc. C. I.

† Aurichalcum ex ære fit, cum igne multo; et medicamine adhibito, perducitur ad aureum colorem.
Prima. in Apo. C. I.

‡ Aurichalcum dictum, quod et splendorem auri, et duritiam æris possideat, fit autem ex ære et igne multo, ac medicaminibus perducitur ad aureum colorem. Ind. Orig.

‖ Hist. Nat. L. XXXIV. C. 10.

either Orichalcum, or a ſubſtance imitating the goodneſs of Orichalcum, we cannot have much doubt in ſuppoſing, that *cadmia* was the drug alluded to by *Ambroſe*, and of thoſe who ſeem to have borrowed, with ſome inaccuracy of expreſſion, his deſcription of the manner of making Orichalcum.

What we call braſs was anciently in the French language called *archal*, and braſs wire is ſtill not unfrequently denominated *fil d'archal*. Now if we can infer, from the analogy of languages, that *archal* is a corruption of *aurichalcum*, we may reaſonably conjecture, that our braſs, which is the ſame with the French *archal*, is the ſame alſo with the Roman *aurichalcum*.

Though we may, from what has been advanced, conclude, without much apprehenſion of error, that the Romans knew the method of making braſs, by melting together calamine and copper; yet the invention was probably derived to them from ſome other country.

We meet with two paſſages, one in *Ariſtotle*, the other in *Strabo*, from which we may collect, that braſs was made in *Aſia*, much after the ſame manner, in which it appears to have been made at Rome.

Strabo informs us, that in the environs of *Andera*, a city of *Phrygia*, a wonderful kind of ſtone was met with, which being calcined became iron, and being then fluxed with a

certain earth, dropped out a ſilver-looking metal, which, being mixed with copper, formed a compoſition, which ſome called Orichalcum.* It is not improbable, I think, that this ſtone reſembled *black jack*, or ſome other ore of zinc. Black jack may, in a common way of ſpeaking, be called a ſtone. It abounds in iron; and, when calcined, looks like an iron earth: it yields zinc by diſtillation, ſometimes mixed with ſilver and lead; and both the metallic ſubſtance which may be extracted from black jack, and, the ſublimate which ariſes from it whilſt it is ſmelted, will, when mixed with copper, make braſs.

The *Moſſynæci* inhabited a country not far from the *Euxine* Sea, and their copper, according to *Ariſtotle*, was ſaid to have become ſplendid and white, not from the addition of tin, but from its being mixed and cemented with an earth found in that country.† This cementing copper with an earth, is what is done, when braſs is made, by cementing copper with calamine, which is often called, and, indeed, has the external appearance of, an earth: and that Aſia was celebrated for its cadmia or calamine, we have the teſtimony of Pliny.‡ The copper of the Moſſynæci is ſaid to have become *white* by

* Stra. Geo. L. XIII.

† Ariſ. de Mirab. Op. Tom II. p. 721.

‡ Hiſt. Nat. L. XXXIV. C. 2.

this

this operation. Whiteneſs appertains to braſs either abſolutely, or relatively: for braſs is not only much whiter than copper, but when it is made with a certain quantity of a certain ſort of calamine, for there are very various ſorts of it, its ordinary yellow colour is changed into a white. Cicero, we have ſeen, ſuppoſes that Orichalcum might have been miſtaken for gold, and as ſuch, it muſt have been yellow; yet Virgil applies the epithet white to Orichalcum,

> Ipſe dehinc auro ſqualentum *alboque* orichalco
> Circumdat loricam humeris.*

Ariſtotle alſo ſpeaks of having heard of an *Indian* copper, which was ſhining, and pure, and free from ruſt, and not diſtinguiſhable in colour from gold;† and he informs us, that amongſt the veſſels of *Darius* there were ſome of which, but for the peculiarity of their *ſmell* it would have been impoſſible to ſay, whether they were made of gold or copper. This account ſeems very deſcriptive of common braſs, which may be made to reſemble gold perfectly in colour, but which, upon being handled, always emits a ſtrong and peculiar *ſmell*, not obſervable either in gold or gilded copper.

* Vir. Æn. L. XII. 87.

† Arif. de Mirab. T. II, p. 719.

The kings of *Persia*, who preceded the *Darius* mentioned by *Aristotle*, were in possession of similar vessels; but they seem to have been rare, and, of course, were held in high estimation. Among the magnificent presents of gold and silver vessels, which *Artaxerxes* and his counsellors gave to *Ezra*, for the service of the temple at *Jerusalem*, there were twenty basons of gold, and but two vessels of *yellow* shining copper, precious as gold, or, as some render the words, resembling gold.* "Sir John Chardin, in his MS. note, has mentioned a mixt metal used in the east, and highly esteemed there; and, as the origin of this composition is unknown, it might, for aught we know, be as old as the time of *Ezra*, and be brought from those more remote countries into *Persia*, where these two basons were given to be conveyed to Jerusalem. *I have heard*, says the note, *some Dutch Gentlemen speak of a metal in the island of Sumatra, and among the Macassars, much more esteemed than gold, which royal personages alone might wear. It is a mixture, if I remember right, of gold and steel, or of copper and steel. He afterwards added to this note (for the colour of the ink differs) Calmbac is this metal composed of gold and copper. It in colour nearly resembles the pale carnation rose, has a very fine grain, the polish extremely lively. I have seen some-*

* Ezra, viii. 27.

thing

thing of it, &c. Gold is not of ſo lively and brilliant a colour; I believe there is ſteel mixed with the gold and copper. He ſeems to be in doubt about the compoſition, but very poſitive as to its beauty and high eſtimation."*

The ſuppoſition of braſs having been anciently made in *India*, ſeems to be rendered improbable by both *Pliny* and *Strabo*; Pliny expreſsly ſaying, that the Indians had no copper, † and without copper we are certain that braſs cannot be made; and Strabo repreſenting them as ſo ignorant of the art of fluxing metals, ‡ that, according to him, if they had been poſſeſſed of the materials, they would not have had the ability to uſe them for the compoſing of braſs. But theſe writers, it is apprehended, knew very little of India. Strabo, in particular, laments his want of materials to compoſe a conſiſtent account of India; and few of the authors, from whoſe works Pliny compiled his natural hiſtory, can be ſuppoſed to have had any intercourſe with that country. Strabo, moreover, contradicts both Pliny's obſervation, and his own. In deſcribing the great pomp with which ſome of the Indians were accuſtomed to celebrate their feſtivals, he ſpeaks of huge gilt kettles, cups, and tables

* Harmer's Obſ. on Scrip. Vol. II. p. 491.

† Hiſt. Nat. L. XXXIV. C. 17.

‡ Geo. L. XIV.

made

made of *Indian* copper;* from which it appears, not only that the Indians were not destitute of copper, but that they were skilful metallurgists, since they knew how to flux it, to form it into vessels of various kinds, and to gild it. Perhaps, this Indian copper, of which the vessels were made, instead of being gilt, only resembled gold in colour, and was really a sort of brass. It is granted that this is but a conjecture, but it is not devoid of probability; for, not to mention that the author, whoever he was, from whom Strabo extracted this account, might, in a public exhibition, have easily mistaken polished brass for gilt copper, nor the little probability, that cauldrons, and kettles, and such vessels as were in constant use, would be gilded in any country, we have reason to believe, from what has been observed before, that a peculiar kind of vessels, probably resembling some of those exhibited in the Indian festivals, had been long in use in *Persia*, and that they were made of Indian copper without any gilding. We know that there is found in India, not only copper strictly so called, but zinc also, which being mixed with copper constitutes brass, pinchbeck, tombac, similor, and all the other metallic mixtures which resemble gold in colour. On the whole, it appears probable to me, that brass was

* Id. LXXVI.

made

made in the moſt remote ages in *India*, and in other parts of *Aſia*.

With reſpect to Orichalcum, it is generally ſuppoſed that there were two ſorts of it, one factitious, the other natural; the factitious, whether we conſider its qualities or compoſition, appears to have been the ſame with our braſs. As to the natural Orichalcum, there is no impoſſibility in ſuppoſing, that copper ore may be ſo intimately blended with an ore of zinc, or of ſome other metallic ſubſtance, that the compound, when ſmelted, may yield a mixt metal of a paler hue than copper, and reſembling the colour of either gold or ſilver. In *Du Halde*'s hiſtory of *China*, we meet with the following account of the Chineſe *white copper*. "The moſt extraordinary copper is called *De-tong*, or white copper: it is white when dug out of the mine, and ſtill more white within than without. It appears by a vaſt number of experiments made at *Peking*, that its colour is owing to no mixture; on the contrary, all mixtures diminiſh its beauty; for, when it is rightly managed, it looks exactly like ſilver, and were there not a neceſſity of mixing a little *Tutenag*, or ſome ſuch metal with it, to ſoften it, and prevent its brittleneſs, it would be ſo much the more extraordinary, as this ſort of copper is, perhaps, to be met with no where but in China, and that only in the

province

province of *Yun-nan.*" * Notwithstanding what is here said, of the colour of this copper being owing to no mixture, it is certain, that the Chinese white copper, as brought to us, is a mixt metal; so that the ore, from which it is extracted, must consist of various metallic substances, and from some such ore it is possible that the natural Orichalcum, if ever it existed, may have been made. But, notwithstanding that the existence of natural Orichalcum cannot be shewn to be impossible, yet there is some reason to doubt, whether it ever had a real existence or not.

We know of no country in which it is found at present; nor was it any where found in the age of *Pliny*; nor does he seem to have known the country where it ever had been found. He admits, indeed, its having been formerly dug out of the earth; but it is remarkable that in the very passage, where he is mentioning by name the countries most celebrated for the production of different kinds of copper, he only says, in general, concerning Orichalcum, that it had been found in other countries, without specifying any particular country. *Plato* acknowledges, that Orichalcum was a thing only talked of even in his time; it was no where then to be met with, though in the island of *Atlantis*

* Fol. Trans. Vol. I. p. 16.

it

it had been formerly extracted from its mine. The *Greeks* were in possession of a metallic substance, called Orichalcum, before the foundation of *Rome*; for it is mentioned by *Homer*, and by *Hesiod*, and by both of them in such a manner as shews, that it was then held in great esteem. Other ancient writers have expressed themselves in similar terms of commendation; and it is principally from the circumstance of the high reputed value of Orichalcum, that authors are induced to suppose the ancient Orichalcum to have been a natural substance, and very different from the factitious one in use at Rome, and, probably, in Asia, and which, it has been shewn, was nothing different from our brass.

But this circumstance, when properly considered, does not appear to be of weight sufficient to establish the point. Whenever the method of making brass was first found out, it is certain that it must have been for some time, perhaps for some ages, a very scarce commodity; and this scarcity added to its real excellence as a metallic substance, must have rendered it very valuable, and intitled it to the greatest encomiums. *Diodorus Siculus* speaks of a people, who willingly bartered their gold for an equal weight of iron or copper;* and the Europeans have long carried on a similar

* Lib. III.

kind

kind of commerce with various nations. Gold, in ſome views, is juſtly eſteemed the moſt valuable of metals; in others, and thoſe the moſt important to the well-being of human kind, it is far inferior to iron, or copper or braſs. An individual, whoſe life depended upon the iſſue of a ſingle combat, to be decided by the ſword, would have no heſitation in preferring a ſword of ſteel, to one of gold; and an army, which ſhould be poſſeſſed of golden armour, would not ſcruple to exchange it, in the day of battle, for the iron accoutrements of their enemies. The preference of the harder metals to gold, is not leſs obvious in agriculture, than in war; a plough-ſhare, ſpade, mattock, chizel, hammer, ſaw, nail, of gold, is not for uſe ſo valuable, as an inſtrument of the ſame kind made of iron or braſs. Hence, there is no manner of abſurdity in ſuppoſing that Orichalcum, when firſt introduced among the ancients, might have been prized at the greateſt rate, though it had been poſſeſſed of no other properties, than ſuch as appertain to braſs. When iron was either not at all known, or not common in the world, and copper inſtruments, civil and military, were almoſt the only ones in uſe,* a metallic mixture, reſembling gold in ſplendour, and preferable to copper, on account of its ſuperior hardneſs, and being leſs liable to ruſt, muſt have greatly

* Heſiod.

excited

excited the attention of mankind, been eagerly ſought after, and highly extolled by them. The *Romans*, no doubt, when it had been ſtipulated in the league which *Porſenna* made with them, after the expulſion of the *Tarquins*, that they ſhould not uſe iron, except in agriculture, muſt have eſteemed a metallic mixture ſuch as braſs, at a rate not eaſily to be credited.* It is not here attempted to prove, that there never was a metallic ſubſtance called Orichalcum, ſuperior in value and different in quality from braſs; but merely to ſhew, that the common reaſon aſſigned for its exiſtence, is not ſo cogent as is generally ſuppoſed.

Conſidering the few ancient writers we have remaining, whoſe particular buſineſs it was to ſpeak with preciſion concerning ſubjects of art, or of natural hiſtory, we ought not to be ſurprized at the uncertainty in which they have left us with reſpect to Orichalcum. Men have been ever much the ſame in all ages; or, if any general ſuperiority in underſtanding is to be allowed,

* In fœdere quod, expulſis regibus, populo Romano dedit Porſenna, nominatim comprehenſum invenimus, ne ferro niſi in agricultura uterentur Plin. Hiſt. Nat. Vol. II. p. 666. Was Porſenna induced to prohibit the Romans the uſe of iron arms, from the opinion, which ſeems to have prevailed in Greece two hundred years afterwards— that wounds, made with copper weapons, were more eaſily healed, than thoſe made with iron? Ariſt. Op. L. IV. p. 43.

it

it may ſeem to be more properly aſcribed, to thoſe who live in the manhood or old age of the world, than to thoſe who exiſted in its infancy or childhood: eſpecially as the means of acquiring and communicating knowledge are, with us, far more attainable than they were in the times of either Greece or Rome. The Compaſs enables us to extend our reſearches to every quarter of the globe with the greateſt eaſe; and an hiſtorical narration of what is ſeen in diſtant countries, is now infinitely more diffuſed than it could have been, before the invention of printing; yet, even with theſe advantages, we are, in a great meaſure, ſtrangers to the natural hiſtory of the earth, and the civil hiſtory of the nations which inhabit it. He who imports *Tutenag* from the Eaſt Indies, or *white copper* from *China* or *Japan*, is ſure of meeting with a ready market for his merchandize in *Europe*, without being aſked any queſtions concerning the manner how, or the place where, they are prepared in *Aſia*. An ingenious manufacturer of theſe metallic ſubſtances might wiſh, probably, to acquire ſome information about them, in order to attempt a domeſtic imitation of them; but the merchant who imports them, ſeems to be too little intereſted in the ſucceſs of his endeavours, to take much pains in procuring for him the requiſite information. Imitations, however have been made of them, and we have an European *Tute-*

nag,

nag, and an European white copper, differing, in ſome qualities, from thoſe which are brought from Aſia, but reſembling them in ſo many others, that they have acquired their names. Something of this kind may have been the caſe with reſpect to Orichalcum, and the moſt ancient Greeks may have known no more of the manner in which it was made, than we do of that in which the Chineſe prepare their white copper: they may have had too, an imitation of the original, and their authors may have often miſtaken the one for the other, and thus have introduced an uncertainty and confuſion into their accounts of it.

There is as little agreement amongſt the learned concerning the etymology of Orichalcum, as concerning its origin. Thoſe who write it *Aurichalcum*, ſuppoſe that it is an hybridous word, compoſed of a Greek term ſignifying copper, and a Latin one ſignifying gold. The moſt general opinion is, that it ought to be written *Orichalcum*, and that it is compounded of two Greek words, one ſignifying copper, and the other a mountain, and that we rightly render it by, Mountain Copper. I have always looked upon this as a very forced derivation, inaſmuch as we do not thereby diſtinguiſh Orichalcum from any other kind of copper; moſt copper mines, in every part of the world, being found in mountainous coun-

tries. If it ſhould be thought, that ſome one particular mountain, either in Greece or Aſia, formerly produced an ore, which being ſmelted yielded a copper of the colour of gold, and that this copper was called Orichalcum, or the mountain copper, it is much to be wondered at, that neither the poets nor the philoſophers of antiquity have beſtowed a ſingle line in its commendation; for as to the *Atlantis* of *Plato*, before mentioned, no one, it is conceived, will build an argument for the exiſtence of natural Orichalcum, on ſuch an uncertain foundation: and, if there had been any ſuch mountain, it is probable, that the copper it produced would have retained its name, juſt as at this time of day we ſpeak of Ecton copper in Staffordſhire, and of Paris—mountain copper in Angleſea.

Some men are fond of etymological inquiries, and to them I would ſuggeſt a very different derivation of Orichalcum. The Hebrew word *Or*, *Aur*, ſignifies light, fire, flame; the Latin terms *uro* to burn, and *aurum* gold, are derived from it, inaſmuch as gold reſembles the colour of flame; and hence, it is not improbable, that Orichalcum may be compoſed of an Hebrew, and a Greek term, and that it is rightly rendered, *flame coloured copper*. In confirmation of this it may be obſerved, that the Latin epithet *lucidum*, and the Greek one φαεινον, are both

both applied to Orichalcum by the ancients; but I would be underſtood to ſubmit this conjecture, with great deference, to thoſe who are much better ſkilled, than I am, in etymological reſearches.

REMARKS *on the* ORIGIN *of the* VEGETABLE FIXED ALKALI, *with ſome collateral* OBSERVATIONS *on* NITRE. *By* M. WALL, M. D. *Prælector in Chemiſtry, in the Univerſity of Oxford. Communicated in a Letter to Dr. Percival. Read November* 19, 1783.

OXON, OCTOBER 1, 1783.

THE extenſive employment of the Vegetable Alkali and Nitre in many of the principal operations of Chemiſtry, renders every inquiry into their origin and properties, not ſimply amuſing, but intereſting in a very high degree to every lover of this ſcience, and to every one engaged in the arts dependent upon it. It is not, however, with the pretenſion of advancing any thing perfectly new, that I have preſumed to offer the following remarks to the conſideration of the Society. My hopes will be fully anſwered, if I ſhould turn the thoughts of any of theſe ingenious Gentlemen, who have done

 me

me the honour to aſſociate me with them, to theſe ſubjects, ſo far as to lead to any new experiments, by which the qualities and preparation of articles ſo important may be more perfectly inveſtigated and explained, and the great expence attending the preſent mode of preparing or importing them diminiſhed.

The very curious proceſs, diſcovered by Mr. Birch, and related by you, Sir, with ſo much perſpicuity in the Philoſophical Tranſactions, for procuring the vegetable alkali from the water of dunghills, may be adduced as a proof, that very conſiderable improvements have been lately made in the preparation of this ſalt. And as the ſum paid by the nation to Ruſſia, and other foreign ſtates, is no leſs than one hundred and fifty thouſand pounds per annum, for pot-aſh,* every hint towards an improvement that can be ſuggeſted in its preparation, is valuable, eſpecially as it is not impoſſible, that we may now alſo loſe, in a conſiderable degree, the advantage of that, which has been hitherto prepared for the uſe of theſe iſlands in North America.

This alkali, having been long obtained ſolely by the combuſtion of vegetable ſubſtances, was by moſt chemiſts conſidered, as a production of the fire, formed by ſome ſecret combination of the earthy, and perhaps ſome portion of the in-

* *Watſon's* Eſſays, Vol. I. p. 135.

flammable

flammable part of the plant, with the native acid, the aqueous part being diſſipated in the proceſs.

On the other hand, it was by a few perſons conjectured, that the alkali exiſts in vegetables perfectly formed previouſly to the combuſtion; and that the operation of the fire is nothing more, than a perfect ſeparation and diſſipation of the other principles, by which it was entangled and concealed.

In confirmation of this latter opinion, it was alledged, that Meſſrs. *Beaumé* * and *Boulduc*,† &c. had extracted nitre, and other ſalts, of which this alkali is the baſe, from ſeveral plants by infuſion and decoction, without incineration. In anſwer to theſe obſervations it was advanced that the nitre, &c. thus detected, muſt be conſidered as foreign, adventitious, and not eſſential to the plant, becauſe from the ſame ſpecies the quantity obtained at different times is extremely variable. Its exiſtence, therefore, at all in plants, muſt be aſcribed to ſome peculiar circumſtances of culture and ſoil; and in proof of this, it was remarked, that it frequently happens, that the ſame plants which contain much nitre, when theſe two circumſtances favour its introduction, contain none at all in contrary circumſtances.

* Dict. of Chemiſtry, Article, Alkali Fixed Vegetable.

† Encycloped. Art. Nitre and Mem. del Acad. des Sciences. 1734.

Of theſe two opinions, that which inſinuates that the alkali exiſts in vegetables in its perfect ſtate, can hardly be admitted, at leaſt until we have accumulated a larger collection of facts relative to this point. It is much more probable, that the alkali, wherever it is found, whether in conſequence of combuſtion or otherwiſe, is formed by ſome tranſmutation (if I may be allowed the expreſſion) of the native acid of plants, or by a particular combination of it with the earthy and inflammable principles.

I am inclined to adopt this doctrine, from the three following circumſtances, the two laſt of which will alſo ſhew, that this tranſmutation may be effected without combuſtion, and therefore, that this alkali cannot be any longer conſidered as the *creature* or *offspring* of fire.

Firſt, Thoſe vegetable ſubſtances, which contain the largeſt portion of the native acid, afford the largeſt quantity of alkali by incineration: and the quantity of alkali obtained is very conſiderably increaſed by particular modes of applying the heat, which can only be underſtood to operate, by bringing the ſeveral component principles of the vegetable ſubſtance into cloſer contact, and within the ſphere of each other's action.

Secondly, This alkali is produced in a very conſiderable quantity by the proceſs of fermentation, to which only the ſaccharine and aceſcent parts of plants are liable. And,

Thirdly,

Thirdly, It is produced in the putrefaction both of animal and vegetable matters.

In the two laſt of theſe caſes, we have not indeed hitherto obtained the alkali ſeparate, but in combination with acids forming nitrous and other neutral ſalts.

I. To confirm the firſt of the poſitions above ſtated, it is only requiſite, before this Society, to obſerve, that no vegetable ſubſtances furniſh a larger quantity of alkali than the extracts of plants, or their native eſſential ſalts. And in the common mode of preparing this alkali by incineration, it has been often remarked, that even when thoſe vegetable ſubſtances, which abound with acid, are burnt with a cloſe ſmothering heat (as in making the alkaline ſalt of *Tachenius)* the greateſt part of the acid is gradually diſſipated, and very little alkali is obtained; whereas, by a quick open fire, the acid ſeems to be intimately coagitated with the earthy part before ſuch a diſſipation can take place, and the produce of the alkali is vaſtly larger. It is a common obſervation, how minute a proportion of alkali the aſhes of charcoal yield, compared to that which may be obtained by burning an equal quantity of the ſame wood in an open fire.*

II. That the vegetable alkali is produced copiouſly in the natural proceſs of vinous fer-

* *Neumann*'s Chemiſtry, by *Lewis*, Vol. II. p. 290.

mentation, appears evinced by the celebrated *Scheele*'s curious analyfis of the tartar of wine. *

This fubftance was long confidered fimply as a peculiar acid, debafed, perhaps, by a large admixture of earthy matter: but no one before Mr. *Scheele* ever conceived, that it was a neutral falt, with a vegetable alkaline bafe. Yet fuch his experiments have fhewn it to be, the alkali being, however, furperfaturated with the vegetable acid.

His principal experiment (which I relate, not as fuppofing it unknown to the Gentlemen of the Society, but only to recal it to their remembrance) was as follows:

He diffolved cream of tartar in a fufficient quantity of boiling water, and added fine chalk in powder to it until the effervefcence ceafed: a copious white fediment fell to the bottom, which was the chalk, combined with a part of the acid of tartar; and the liquor, that floated above the precipitate, afforded, by careful evaporation, a cryftallization of foluble tartar, which is a compound of the acid of tartar, with the vegetable alkali. Though perfectly fatisfied of the accuracy of *Scheele*, and of Dr. *Black*, who re-

* The original account of thefe experiments is given in the Swedifh Tranfactions for the year 1770, but as that work is not common in this kingdom, it may be ufeful to refer to an Abftract of this Memoir in the Medical Commentaries, Vol. I. p. 320.

peated

peated these experiments with the same success, I was desirous of obtaining a confirmation of this fact, by a different mode; and as I do not remember to have seen the process in any chemical work, I shall trouble the Society with an account of it.

I poured, upon an ounce of cream of tartar, nearly a pint of boiling water, and immediately added two ounces of Glauber's spirit of nitre, conceiving that the latter, by its strong attraction to the vegetable alkali (so superior to that of the acid of tartar) would, if that alkali existed in tartar, detach it from its union, and form with it a perfect nitrre. Immediately upon the addition of the nitrous acid, the cream of tartar was dissolved; much sooner than might have been expected, from the quantity of water employed; but the solution was probably expedited by the change which took place upon the addition of the nitrous acid. The mixture was then set in the heat of a water-bath, and evaporated to the proper degree for crystallization; and being then placed in the cold, afforded a dram of well-formed crystals, which appeared, both by their figure and taste, and by deflagrating with charcoal, to be perfect nitre.*

From

* The quantities of the cream of tartar and spirit of nitre, used in these experiments, were taken at random, I was only solicitous to employ so much of that latter, as might

From these experiments on cream of tartar, the following conclusions result: "That this substance is not, as has been commonly supposed, a peculiar acid, joined with impurities, but that it is really a compound salt, containing an alkali joined with an acid; and further, that the alkaline salt, obtained from tartar by incineration, is not generated in the fire, but was actually pre-existent in the tartar." *

might be quite sufficient to detach all the alkali. By future trials, the proportion might be so nicely adjusted, as exactly to answer this intention, and thereby the acid of tartar might be left, after the crystallization, perfectly pure and distinct.

I evaporated the fluid remaining after the crystallization still farther, and endeavoured, by the same mode of treatment, to obtain more crystals, but without success. The evaporation was carried on, until the mass became thick and tenacious. When set in the cool, it did not deliquiate, or attract any moisture, though I kept it a fortnight in very damp weather. By this circumstance, and by the taste, I judged to be principally, almost entirely, a pure concrete acid of tartar, rendered a little more sharp and penetrating by the adhesion of a little of the acid of nitre, which probably a longer continuance, and a little increase of the heat, would have dissipated. May not these experiments, in conjunction with those of Mr. *Scheele*, (who has also shewn that the acid of tartar may be obtained pure in a concrete state) lead to an improvement in the preparation of tartar emetic?—But as this subject is not within the plan prescribed for dissertations of this kind, I shall trouble the Society with only this slight hint.

* Med. Comment. ut. supr.

III. The

III. The vegetable alkali ſeems alſo to be, in ſome inſtances, generated or formed by putrefaction; for nitre, of which it is an eſſential part, is often the product of a putrefactive proceſs.

It has long been a received doctrine in chemiſtry, that the nitrous acid owes its origin to putrefaction: but that the alkali of nitre is derived from that ſource, may appear a novel opinion; and yet it is deducible from the lateſt obſervations, which have been made relative to the generation of nitre.

When it was firſt related by travellers from the Eaſt Indies, that nitre was there found on the ſurface of the ground, perfectly formed; and that it was ſwept up and collected for uſe, without any other preparation; the account was conſidered in Europe, as at leaſt erroneous, and derided as inconſiſtent with the moſt eſtabliſhed facts, concerning the formation of this ſalt. It was alledged that nitre, wherever produced by any thing like a natural proceſs, is always imperfect, having a calcareous, inſtead of an alkaline baſe; that to make it perfect, a freſh ſolution, with the addition of wood-aſhes, was indiſpenſably requiſite, both for its purification, and to ſupply the vegetable alkali. This, in particular, was the language of *Neumann*,* a

* *Neumann*'s Chemiſtry, by *Lewis*, Octavo, Vol. I. p. 306.

chemiſt

chemiſt of no mean reputation, who may alſo, without much impropriety, be conſidered as a modern writer, his Diſſertation on Salt Petre being publiſhed ſo lately as the year 1732. This doctrine, concerning nitre, cannot therefore be conſidered as antique, and on that account, rejected as weak and groundleſs.—Yet later obſervations have fully ſhewn, that this theory has been formerly too ſtrongly inſiſted upon. Authentic accounts of the mode of collecting nitre in the eaſt, very correſpondent with that alluded to above, have been ſince received from China, and the coaſt of Coromandel, which are cited by Dr. *Watſon*, * and prove at leaſt (though more diſputable inferences may have been drawn from them) that nitre may be formed without the aſſiſtance of art, or at leaſt, without the addition of a vegetable alkali, or wood-aſhes. The account given by Mr. *Bowles*, † of the manner in which nitre is collected in Spain, ſtrongly confirms this aſſertion. In both theſe inſtances, perfect nitre is obtained from the ſuperficial mould of the ſoil, only previouſly ploughed, and piled up in heaps. This mould or ſurface of the earth is formed in ſituations, like thoſe above alluded to, remote from the habitations and reſidence of men or cattle, entirely from the

* *Watſon*'s Eſſays, Vol. I. p. 307.

† *Dillon*'s Tranſlation of Don *Bowles*'s Travels in Spain, p. 42.

decayed

decayed and decaying parts of vegetables, advanced and advancing to the ſtate of putrefaction. As it appears, therefore, that true nitre is produced in this proceſs, it is obvious, that the vegetable alkali is produced by the operation of nature only, in the putrefaction of vegetables.

That nitre is produced in the putrefaction of animal matters, has been confidently aſſerted by ſome chemiſts, and as confidently denied by others. Inſtances are alledged on the one hand, of nitre procured from putrefied blood, urine, &c. On the other hand it is argued, that theſe ſubſtances will not ſupply the materials of nitre, without the concurrence of ſome vegetable matter. To diſcuſs this point thoroughly, would take a great deal of time, and requires extenſive abilities; but I think there is a common and familiar fact, which may be adduced to illuſtrate it. It will at leaſt prove, that if nitre (and of courſe the vegetable alkali) is not obtainable from the putrefaction of animal matters only, the addition of a very ſmall quantity of vegetable matter is ſufficient for its production. I argue from the quality of the ſaline efflorefcence found on old walls, which are expoſed to impregnation from animal matters in a ſtate of putrefaction. The wall of one end of my chemical ſchool, or laboratory, is almoſt entirely covered with ſuch an efflorefcence. The laboratory, is a large vaulted room under ground, into which the

the ſun ſeldom has admiſſion. It is built of ſtone, and therefore, except when the fires are kept up for the lectures, or occaſional experiments, is liable to be damp. The wall, to which I allude, is immediately under a retired paſſage, a very convenient place of retreat to foot-paſſengers under certain circumſtances of neceſſity. The ground, therefore, and the adjacent wall have been for years largely impregnated with excrementitious animal fluids, in all the different ſtages of putrefaction. The ſaline efflorefcence on ſuch walls is ſometimes ſuppoſed to be alkaline, and really to be the foſſile alkali; but that in this inſtance, with which others of a ſimilar ſort probably have ſome analogy, it was perfect nitre, the following remarks will evince.

The ſalt deflagrates readily with charcoal, or ſulphur, and leaves an alkali exactly ſimilar in taſte to that of the nitrum fixum. It does not deflagrate per ſe—It does not give out the ſmell of hartſhorn, or the volatile alkali, when lixivium tartari is poured upon it either in a diſſolved, or a dry ſtate. A filtered ſolution of it ſuffers no precipitation, on the addition of lixiv. tartari. A ſmall quantity of this ſolution evaporated to cryſtallization ſhoots into long, filamentous, not cubical, cryſtals, exactly the ſame as thoſe obtained from an equal quantity of ſolution of nitre, by the ſame mode of treatment; and indeed, the effloreſcence on the walls, where

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it can be ſeen free from duſt, examined with a magnifier, appears to be formed by a congeries of ſpicula of this oblong hexaëdral form, a mode of cryſtallization, which neither the foſſile alkali, nor cubic nitre effect. Theſe experiments ſhew, that the nitre thus collected, has neither a calcareous, nor a volatile alkaline, nor a foſſil alkaline, baſe, but is in every reſpect perfect nitre, generated principally by the putrefaction of animal matters, certainly without the artificial addition of any prepared vegetable ſubſtance, (prepared at leaſt by fire) to ſupply the vegetable alkali.

If you ſhould think, Sir, upon peruſal, that theſe obſervations will afford any amuſement to the Society, you will oblige me by communicating them. If, on the other hand, you ſhould think them too trifling, ſuperficial, or tedious, I beg the favour of you to ſuppreſs them. And am,

With great regard,

Your ſincere friend, and humble ſervant,

M. WALL.

Some ACCOUNT *of the* LIFE *and* WRITINGS *of the late* PROFESSOR GREGORY, M. D. F. R. S.— *By* JAMES JOHNSTONE, M. D. *and Soc. Reg. Medi. Edinb. Socius. Communicated by Dr. Barnes. Read December* 10, 1783.

JOHN GREGORY, M. D. F. R. S. Fellow of the Royal College of Phyſicians in Edinburgh, and Profeſſor of Medicine in the Univerſity of Edinburgh, born at Aberdeen in 1725, was third ſon of JAMES GREGORY, M. D. Profeſſor of Medicine in King's College, Aberdeen; and of Anne, daughter of the Rev. George Chalmers, Principal of King's College there. The family of Dr. Gregory is of great antiquity in Scotland, and has for more than a century paſt produced a ſucceſſion of Gentlemen, of the firſt diſtinction in the learned world. JAMES GREGORY, Profeſſor of Mathematics, firſt at St. Andrews, and afterwards at Edinburgh, the Doctor's grandfather, was one of the moſt eminent Mathematicians of the laſt age, the age of Mathematics. He invented the Reflecting Teleſcope, improved by Sir Iſaac Newton. His *Optica Promota*, and other mathematical works, are ſtill in high eſteem.

David

David Gregory of Oxford, another of the family, the Doctor's couſin, publiſhed an excellent and complete Treatiſe of Aſtronomy, founded upon the principles, and explanatory of the doctrine, of Sir Iſaac Newton. James Gregory, M. D. the Doctor's eldeſt brother, ſucceeded their father as Profeſſor of Medicine in King's College, Aberdeen: and the Doctor, of whom we write, has left a ſon, who now holds the office of Profeſſor of the Inſtitutions of Medicine in the Univerſity of Edinburgh, made vacant by the election of Dr. Cullen to be ſole Profeſſor of Practice, after his father's death. It ſeems to be the deſtiny of this family, to enlarge ſcience, and inſtruct mankind; and we hope, it will long hold this honourable diſtinction.

Though Dr. Gregory's father died, when his ſon was very young, his education was carefully and ſucceſsfully conducted by able and ſkilful perſons, who were attached to his father and family, as well as to the duty they owed to their pupil. In ſuch a happy ſituation for improvement, Dr. Gregory made a rapid progreſs in his ſtudies. At Aberdeen, he became thoroughly acquainted with the learned languages, and with his own; here he finiſhed his courſe of philoſophy, and his mathematical ſtudies; for like the reſt of his anceſtors, he was deeply verſed in mathematical knowledge. And in this admirable ſchool, where abſtract ſcience itſelf

 has

has undergone a ſignal reformation, and has learned to ſpeak the language of common ſenſe, and to adorn itſelf with the graces of taſte and eloquence, Dr. Gregory cultivated an elegant and juſt taſte, clearneſs and beauty of expreſſion, with preciſion of judgment, and extenſive knowledge. With the circle of ſcience, he poſſeſſed a great ſhare of common ſenſe, and of the knowledge of men. This he diſplays in his writings; and evidently carried into his profeſſion a ſpirit congenial to that of the Gerard's and Beattie's, Gentlemen, with whom he lived in the cloſeſt habits of friendſhip.

Having finiſhed at Aberdeen his courſe of ſtudy in languages, arts, and philoſophy, in 1742 he went to Edinbugh, to proſecute the ſtudy of medicine.

Having attended the excellent courſes of the late Dr. Alexander Monro, the celebrated Profeſſor, and Father of Anatomy there—of Dr. Alſton, on the Materia Medica, and Botany—of Dr. Plummer, on Chemiſtry—of Dr. Sinclair, the elegant and favourite ſcholar of Boerhaave, on the Inſtitution of Medicine—of the ſagacious Rutherford, on the Practice of Medicine—he went to Leyden in 1745, and to Paris in 1746, for farther improvement.

While at Leyden, he received a ſpontaneous mark of the eſteem in which he was held by thoſe among whom, and by whom, he had been educated,

cated, in having the degree of Doctor of Physic conferred upon him by the University of Aberdeen; and when he returned there from Paris, he was appointed Professor of Philosophy in King's College. He held this professorship for three or four years, and during that time he gave lectures, or rather a complete course, according to the method of education in that university, on the following important branches of knowledge. 1. Mathematics. 2. Natural and Experimental Philosophy. 3. Ethics, and Moral Philosophy.

In 1754 he went to London, where he was chosen Fellow of the Royal Society, and cultivated the acquaintance, and fixed the esteem and friendship, of some of the most distinguished literati there. Edward Montague, Esquire, an eminent mathematician, and worthy man, maintained a firm friendship for the Doctor, founded on the similarity of their manners and studies. His Lady, Mrs. Montague, and George Lord Lyttelton, were of the number of his friends; and it is not improbable but he would have continued in London, and practised there in his profession, if the death of his brother James Gregory, M. D. and Professor of Physic in King's College, Aberdeen, in 1756, had not occasioned his being recalled to his native university, to fill the chair of Professor of Physic, vacant by his brother's death. His occupations in physic

now began to be active: he gave a courſe of lectures in phyſic, and practiſed in his profeſſion, with univerſal applauſe.

In 1766, on the mournful occaſion of the death of Dr. Robert Whytt, the ingenious Profeſſor of the Theory of Phyſic at Edinburgh, Dr. Gregory was called to ſucceed him, as his Majeſty's firſt Phyſician in Scotland; and, about the ſame time, he was choſen to fill the chair of Profeſſor of the Practice of Phyſic, which was juſt reſigned by Dr. Rutherford; the Truſtees of that Univerſity being ever attentive to ſupport the high reputation of the celebrated ſchool of phyſic there, by drawing to it, from every quarter, phyſicians of the moſt approved talents and qualifications in the ſeveral branches of medicine, they are appointed to teach. Dr. Gregory gave three ſucceſſive courſes of practical lectures. Afterwards, by agreement with his ingenious colleague, Dr. Cullen, they lectured alternate ſeſſions, on the Practice and Inſtitutions of medicine, with juſt and univerſal approbation, till the time of Dr. Gregory's death.

The doctor having attained the firſt dignities of his profeſſion in his native country, and the moſt important medical ſtation in the univerſity, far from relaxing from that attention to the duties of his profeſſion which had raiſed him, endeavoured to merit the rank he held in it, and in the public eſteem, by ſtill greater exertions

exertions of labour and aſſiduity. It was during this time of buſineſs and occupation, that he prepared and publiſhed his Practical Syllabus for the Uſe of Students, which, if it had been finiſhed, would have proved a very uſeful book of practice; and likewiſe, thoſe admired Lectures on the Duties, Office, and Studies of a Phyſician.

Dr. Gregory, for many years before his death, felt the approach of diſeaſe, and apprehended, from an hereditary and cruel gout, the premature death, which, indeed, too ſoon put a period to his life and uſefulneſs. In this anxious expectation, he had prepared that admirable proof of paternal ſolicitude and ſenſibility, "A Father's Legacy to his Daughters." But for ſome days, and even that preceding his death, he had been as well as uſual; at midnight, he was left in good ſpirits by Dr. Johnſtone, late Phyſician in Worceſter, at that time his Clinical Clerk; yet, at nine o'clock in the morning of the tenth of February 1773, he was found dead in his bed.*

* He too, Dr. Johnſtone, junior, of Worceſter, has lately fallen a much lamented martyr to a noble diſcharge of duty, in attending the priſoners ill of a fever in Worceſter jail (1783). He attained, at an early period, to great and deſerved eminence in his profeſſion: and will be ever regretted as a phyſician of great ability and genius, and as one of the moſt pleaſing and benevolent of men; prematurely ſnatched from his friends and country, when become highly agreeable and uſeful to them.

Dr. Gregory was tall in perfon, and remarkable for the fweetnefs of his difpofition and countenance, as well as for the eafe and opennefs of his manners. He was an univerfal and elegant fcholar, an experienced, learned, fagacious and humane phyfician—A profeffor, who had the happy talent of interefting his pupils, and of directing their attention to fubjects of importance, and of explaining difficulties with fimplicity and clearnefs. He entered with great warmth into the interefts and conduct of his hearers, and gave fuch as deferved it every encouragement and affiftance in his power: open, frank, focial, and undifguifed in his life and manners, fincere in his friendfhips, a tender hufband and father: an unaffected, chearful, candid, benevolent man—a faithful chriftian. Dr. Gregory's unexpected death, in the heighth of his ufefulnefs, and with appearances which afforded hopes of its continuance for a much longer period, was univerfally lamented as a public, no lefs than a private lofs; and fcience, genius, and worth will long weep over his grave.

Dr. Gregory married in 1752, Elizabeth, daughter of William Lord Forbes: he loft this amiable lady in 1761: fhe left the doctor three fons and three daughters, viz. James Gregory, M. D. now Profeffor of Medicine in Edinburgh—Dorothea—Anne—Elizabeth—William, ftudent of

of Baliol College, Oxford, and now in orders:—John—all now living, except Elizabeth, who died in 1771.

HIS WORKS.

I. Comparative View of the State and Faculties of Man with thoſe of the Animal World.

This work was firſt read to a private literary ſociety at Aberdeen, and without the moſt diſtant view to publication. Many hints are thrown out in it on ſubjects of conſequence, with leſs formality, and more freedom, than if publication had been originally intended. The ſize of the book may have ſuffered by this circumſtance; but the value of the matter has probably been increaſed, by a greater degree of originality, and of variety. The author indulges himſelf in the privileges of an eſſayiſt; he touches many intereſting ſubjects, but with a maſterly, a bold, yet a judicious hand. This work, like another of great fame, may be called a chain, the links of which are very numerous, and yet all connected together. We know the author the better for the rapid judgment he paſſes, and cannot help admiring the goodneſs of his heart, and the benevolence of his views, which have an obvious direction to raiſe the genius, and to mend the heart; and we concur with him in thinking that, " That

view of human nature may be the ſafeſt, which conſiders it as formed for every thing that is good and great, and ſets no bounds to its capacity and power; but looks on its preſent attainments as trifling, and of no account.

The comparative anatomy of brute animals has (as obſerved by our author) been the ſource of moſt uſeful diſcoveries in the anatomy of the human body; but the comparative animal œconomy of mankind, and of other animals—comparative views of their ſtates and manner of life, have been little regarded. Inſtinct is a principle common to us, and the whole animal world: to animals, as far as it extends, it is an infallible guide—In man, reaſon is but a weak principle, and an unſafe guide, when compared to inſtinct. Of this, curious inſtances are mentioned. In the bringing forth, and in the nurſing of their young, the advantages of brute inſtinct over the cuſtoms which have been taken up by rational beings, are placed in a ſtrong light. Numbers of mothers, as well as infants, die by the management of prepoſterous art in child-bearing, and afterwards, by mothers omitting the duty of nurſing—A natural duty and obligation, which contributes no leſs to the ſafety, health, and beauty of mothers, than it does to preſerve the lives and health of their offspring.

The

The recent improvements which have been made in the art of midwifery, and in the methods of nurſing children, are owing to the obſervations of nature, and the imitation of its inſtinctive propenſities.

In this firſt diſcourſe, our author propoſes many improvements of the health and faculties of the human race, by deſerting a luxurious and artificial, and following a natural courſe of life. In this manly way of thinking, he is conſtantly aſſiſted by keeping in view the natural hiſtory of animals, and the manners of ſavage nations, which reſemble them, in following their inſtinctive propenſities.

In the ſucceeding diſcourſes, in which he treats with great perſpicuity, taſte, and diſcernment, of the ſuperior faculties which diſtinguiſh man from the reſt of the animal creation, and of the ſciences and arts founded upon them, he diverges from this comparative view, and loſes ſight of the inferior part of the creation, until he arrives at the following concluſion of this entertaining and ingenious work. "The advantages which ariſe to mankind from thoſe faculties which diſtinguiſh them from the reſt of the animal world, do not ſeem correſpondent to what might be reaſonably expected from a proper exertion of theſe faculties, not even among the few who have the greateſt abilities, and the greateſt leiſure to improve them. The capital

error

error seems to consist, in such men confining their attentions chiefly to inquiries, that are either of little importance, or the materials of which lie in their own minds. The bulk of mankind are made to act, not to reason, for which they have neither abilities, nor leisure. They who possess that deep, clear, and comprehensive understanding which constitutes a truly philosophical genius, seem born to an ascendancy and empire over the minds and affairs of mankind, if they would but assume it. It cannot be expected, that they should possess all those powers and talents which are requisite in the several useful and elegant arts of life; but it is they alone, who are fitted to direct and regulate the application."

The author put his name to the second edition of this work; many additions are also joined to it; and it is dedicated to George Lord Lyttelton, who always professed a high esteem for the author and his writings. This work, in fine, if the author had left no other, must convince every one, that, as a man of science, he possessed extensive knowledge, exquisite taste and judgment, and great liberality of mind and thought; and that, as handsomely said by our instructive poet, Mr. Hayley, in quoting this engaging little volume, in his Essay on Writing History. "He united the noblest affections of the heart to great elegance

elegance of mind; and is juſtly ranked amongſt the moſt amiable of moral writers."

II. OBSERVATIONS on the DUTIES and OFFICES of a PHYSICIAN, and on the Method of PROSECUTING ENQUIRIES in PHILOSOPHY.

This work was firſt publiſhed in 1770, by one, who heard the Profeſſor deliver them in lectures; but they were acknowledged, and republiſhed in a more correct form, by the author, in 1772. In the firſt lecture, the Profeſſor, in repreſenting what the character of a phyſician ought to be, diſplays the moſt noble and generous ſentiments on that ſubject; and all that knew him allow, that no one bore a more exact reſemblance to the fine picture which he here draws, than himſelf.

"The true dignity of phyſic is to be maintained, by the ſuperior learning and abilities of thoſe who profeſs it, by the liberal ſentiments of Gentlemen, and by that openneſs and candour which diſdain all artifice, which invite a free inquiry, and which, by this means, boldly bid defiance to all that illiberal ridicule and abuſe, which medicine has been ſo much expoſed to."

In the ſecond lecture, he ſhews the method of proſecuting inquiries in philoſophy, with an obvious direction to medicine, as one of its principal branches.

III. The next work publiſhed by Profeſſor Gregory is intitled, ELEMENTS of the PRACTICE of

of PHYSIC for the use of STUDENTS, 1772, republished 1774.

The Doctor intended this work as a TEXT BOOK, to be illustrated by his lectures on the practice of physic; but he died before he had finished it, and before he had finished the first course of lectures, which he gave on that text. It is written with great perspicuity and simplicity: the author has intentionally avoided systematical arrangement, perhaps from an opinion, that the art of medicine was yet in too imperfect a state, to admit of any perfect systematical form. However this may be, the work evidently displays the author's great fitness to teach that art. A truly practical genius appears conspicuously in that part of the book, which is thrown into interrogations. Into these, our sagacious author has thrown every thing which had importance to require peculiar attention, as well as those things, which are still matters of doubt and uncertainty, in the practice of medicine.

The Doctor's death happened while he was lecturing on the Pleurisy. His son, Dr. James Gregory, finished that course of lectures, to the general satisfaction of the University; and he therein gave ample proof of his fitness for the station of Professor of Medicine, which he now fills with great honour to himself, and to the University—*Non deficit alter aureus.*

This

This Gentleman publiſhed in 1774, a ſmall tract of his father's, entitled "A FATHER'S LEGACY TO HIS DAUGHTERS:" which was written ſolely for their uſe (about eight years before the author died) with the tendereſt affection, and deepeſt concern for their happineſs. This work is a moſt amiable diſplay of the piety and goodneſs of his heart, and his conſummate knowledge of human nature, and of the world. It manifeſts ſuch ſolicitude for their welfare, as ſtrongly recommends the advice which he gives. He ſpeaks of the female ſex in the moſt honourable terms, and labours to increaſe its eſtimation, whilſt he plainly, yet genteely and tenderly, points out the errors into which young ladies are prone to fall. It is particularly obſervable, in what high and honourable terms he ſpeaks of the Holy Scriptures, of chriſtian worſhip, and faithful miniſters; how warmly he recommends to his daughters the ſerious and devout worſhip of GOD, in public and private. He dwells largely on that temper and behaviour, which were particularly ſuited to their education, rank, and circumſtances; and recommends that gentleneſs, benevolence, and modeſty, which adorn the character of the ladies, and do particular honour to their ſex. His advices, with regard to love, courtſhip, and marriage, are peculiarly wiſe, and intereſting to them. They ſhew what careful obſervation he had made on female do-

meſtic

meſtic conduct, and on the different effects of poſſeſſing or wanting the virtues and qualities which he recommends. There is ſomething peculiarly curious, animated, and uſeful, in his directions to them, how to judge of, and manifeſt an honourable paſſion in, and towards the other ſex, and in the very accurate and uſeful diſtinction which he makes, between true and falſe delicacy. Nothing can be more ſtriking and affecting, nothing more likely to give his paternal advices their deſired effect, than the reſpectful and affectionate manner in which he mentions his lady their mother, and the irreparable loſs which he and they ſuſtained by her early death. In ſhort, in this tract, the Profeſſor ſhines with peculiar luſtre, as a huſband and father, and it is admirably adapted to promote domeſtic happineſs. It is much to be wiſhed, that this tract was re-printed in a cheaper form, that it might be more generally read and regarded. And alſo, that the Doctor's works were re-printed together.

"Adieu, ye lays, that fancy's flowers adorn,
The ſoft amuſement of the vacant mind!
He ſleeps in duſt, and all the Muſes mourn;
He, whom each virtue fired, each grace refined,
Friend! teacher! pattern! darling of mankind!
He ſleeps in duſt!—Ah! how ſhould I purſue
My theme!—To heart-conſuming grief reſigned,
Here on his recent grave I fix my view;
And pour my bitter tears—Ye flowery lays adieu!

Art

Art thou, my Gregory, for ever fled!
And am I left to unavailing woe!
When fortune's ftorms affail this weary head,
Where cares long fince have fhed untimely fnow,
Ah! now for comfort whither fhall I go!
No more thy foothing voice my anguifh chears:
Thy placid eyes with fmiles no longer glow,
My hopes to cherifh, and allay my fears.—
'Tis meet that I fhould mourn—Flow forth afrefh my tears!" *

* Beattie's Minftrel, fecond Book, concluding ftanzas.

On the Knowledge *of the* Ancients *refpecting* Glass, *with a* Sketch *of its* History *down to later* Times. *By Dr.* Falconer. *Read December* 17, 1783.

Ante Chriftum, Ann. 440. Herodotus.

HERODOTUS is, I believe, the moft ancient writer, in whom the word ὕαλος, which is generally underftood to fignify glafs, occurs. He fays, that "the Æthiopians furrounded the dead bodies of perfons of high rank, after being previoufly embalmed, with a cafe of glafs; which fubftance, he adds, is dug up there with eafe, and in plenty. The dead body, he fays, appears, in

in the middle, through the tranſparent covering; neither emitting any ill ſcent, nor being otherwiſe diſagreeable."* It appears, plainly, that artificial glaſs could not be meant here, nor as I ſhould conjecture, rock chryſtal, but in all probability ſomewhat of the talky kind or lapis ſpecularis, which might eaſily be framed, in ſuch a manner, as to form a convenient tranſparent caſe, ſuch as is here deſcribed.

A. C. 400. Ariſtophanes. The next writer, in point of time, that takes notice of glaſs is, I believe, Ariſtophanes, who, in the firſt ſcene of the ſecond act of his Comedy of the Clouds, introduces Strepſiades an old Man, much in debt, informing Socrates of a method he had diſcovered of annulling his own debts.

"You have ſeen, ſays he, among the druggiſts or perfumers, a ſtone which is beautiful and tranſparent, and uſed to kindle fire. Do you mean glaſs? anſwers Socrates. I do, replies the other. What will you do with it? ſays Socrates. When, the other anſwers, the Scribe ſhall have

* Μετα δε ταυτην, τελευταιας εθηησαιτο τας θηκας αυτεων, αι λεγονται σκευαζεσθαι εξ υελου, τροπω τοιωδε. Επεαν τόν νεκροι ισχνηνωσι, ειτε δη καθαπερ Αιγυπτιοι, ειτε αλλως κως, γυψωσαιτες απαντα αυτον, γραφη κοσμεουσι, εξομοιευντες το ειδος ες το δυνατον· επειτα δε οι περιισασι σιηλην εξ υαλου πεποιημενην κοιλην. η δε σφι πολλη ϗ ευεργος ορυσσεται. εν μεση δε τη ςηλη ενεων διαφαινεται ο νεκυς, ουτε οδμην ουδεμιην αχαριν παρεχομενος, ουτε αλλο αεικες ουδεν. ϗ εχει πανταφανεα ομοιως αυτω τω νεκυι. Herod. L. III.

written

written out the proceſs, I, taking this in my hand, and ſtanding in this manner at a diſtance, oppoſite to the Sun, may melt or conſume the letters of the writing." *

We are not, indeed, certain that artificial Glaſs is here underſtood, as the word Υαλος is ſaid to ſignify chryſtal alſo.

It is not, however, at all improbable that glaſs may be here meant, as it will be ſhewn, that the making of it was well underſtood, not many years afterwards. If this be the ſenſe of the paſſage, the manufacture muſt have been brought to conſiderable perfection, as the glaſs, uſed for this purpoſe, muſt have been very clear, and adjuſted by grinding to a proper form for concentrating the ſun's rays, and moreover highly poliſhed.

From the expreſſion (προς τον ηλιον), it might ſeem that a ſpeculum was uſed, ſince the tranſlators render it (adverſus ſolem) oppoſite to the ſun; but it may as well be rendered (inter) between, and then it agrees with the operation of a lens, which, it is plain, this was, from his calling it

* Στρ. Ηδε παρα τοις Φαρμακοπώλαις την λιθον ταυτην έώρακας την καλην, την διαφαιη. αφ' ἧς το πυρ α''πτουσι; Σω. την υαλον λεγεις; Στρ. Εγωγε. Σω. Φερε τι δητ'αν? Στρ. Ειταυτην λαβων, οποτε γραφοιτο την δικην ο γραμματευς, αποτερω σ'ας ωδε προς τον ηλιον, τα γραμματα εντηξαιμι της εμης δικης.

Ariſtoph. Nubes, Act II. Scene I.

διαφανη, or tranſparent.—Ariſtophanes,* in other places, mentions glaſs cups, as uſed for the purpoſes of drinking.

A. C. 340. Ariſtotle. Ariſtotle has two problems, relative to glaſs. The firſt endeavouring to explain its tranſparency, the ſecond, its want of malleability. But the learned think them both to be ſpurious. There is, however, no doubt, that Theophraſtus, the immediate ſucceſſor of Ariſtotle, was well acquainted with glaſs. He deſcribes it as being made of the ſand of the river Belus, † which was called Υελις, to which he adds, that the commoneſt kinds were mixed with copper. The celebrated ſphere of Archimedes,‡ if truly deſcribed, is a remarkable inſtance of the perfection to which the art of making glaſs had been brought, at an early period,

A. C. 303. Theophraſtus.

A. C. 209. Archimedes.

* Επιον ὁ μεν εξ υαλινων εκπωματων. Ariſtoph.

† Ει δε υελος εκ της υελιδος ως τινες φασι κ̀ αυτη πυκνωσει γινεται· ιδιωτατη δε ἡ τω χαλκω μιγνυμενη. Theophr.

Ita (υελις ſcilicet) vocant arenam vitro conflando idoneam, quæ in Beli amnis ripis & alveo reperiebatur.
Salmaſius. Plin. Exerc. p. 773.

‡ An Archimedes Siculus concavo ære ſimilitudinem mundi, ac figuram potuit machinari, in quo ita ſolem, ac lunam compoſuit; ut inæquales motus & cæleſtibus ſimiles converſionibus, ſingulis quaſi diebus efficerent: & non modo acceſſus ſolis, & receſſus, vel incrementa, diminutioneſque lunæ,

period, as well as of great ingenuity in the mechanism and execution of the instrument itself. It seems to have been a kind of orrery or planetarium, in which the sun, moon, and planets, were not only represented in their proper places,

lunæ, verum etiam stellarum vel inerrantium, vel vagarum dispares cursus orbis ille dum vertitur, exhiberet?

Lactant. Lib. II. *De Orig. Erroris.*

Hic est ille noster, cujus ingenio sphæra fabricata, cæli lapsum, & omnium syderum cursus, exemplo divinæ imitationis ostendit. *Jul. Firmic.* L. VI. Cap. 31.

Claudiani Epigramma in Sphæram Archimedis.

Jupiter in parvo cum cerneret æthera vitro,
Risit, & ad superos talia dicta dedit:
Huccine mortalis progressa potentia curæ?
Jam meus in fragili frangitur orbe labor.
Jura poli, rerumque fidem, legesque Deorum
Ecce Syracosius transtulit arte senex.
Inclusus variis famulatur Spiritus astris,
Et vivum, certis molibus urget opus.
Percurrit proprium mentitus signifer annum,
Et simulata novo Cynthia mense redit.
Jamque suum volvens audax industria mundum,
Gaudet, & humanâ sidera mente regit.
Quid falso insontem tonitru Salmonea miror?
Æmula naturæ parva reperta manus.

Nam quum Archimedes lunæ, Solis, quinque errantium motus in Sphærâ illigavit, effecit idem quod ille qui in Timæo mundum exædificavit Platonis Deus, ut tarditate & celeritate dissimillimos motus una regeret conversio.

Cicer. Tusc. Quæst. Lib. I.

according to the aſtronomical ideas that then prevailed, but alſo made to move in their orbits according to their different degrees of velocity. The meridians, the zodiac, with its ſigns, and other great circles of the heavens, together with the riſe and ſetting of the ſtars, were all expreſſed. The whole of this curious mechaniſm, was incloſed in glaſs, and ſeems to have been in form of a ſphere. Whether the celeſtial circles, together with the fixed ſtars, were delineated on the outer glaſs covering, which might be made to revolve round the reſt of the planetary ſyſtem, like that deſcribed in the firſt volume of Dr. Long's Aſtronomy, and the print of it prefixed to the title of that book; or whether it was conſtructed in any other manner, is not clear. It muſt, at any rate, have been a ſurpriſing piece of mechaniſm.

A. C. 105. Lucretius was undoubtedly well acquainted with glaſs, and its properties. In his fourth book, he remarks the difference between ſounds, and the images of objects. The former paſſing through any openings however curved or winding,* whilſt the latter are broken and confuſed, if the paſſages,

* - - - - - - - - - - Vox per flexa foramina rerum
Incolumis tranſire poteſt, ſimulacra renutant.
Perſcinduntur enim, niſi recta foramina tranant,
Qualia ſunt vitri, ſpecies quæ travolat omnis.
Lucret. L. IV. Lin. 603.

through

through which they come, be not direct or rectilinear.

This, though only true, with some limitations, shews him to have had no inconsiderable knowledge of the nature of the subject in question.

A. C. 39. Virgil,* when he means to commend the clearness of the Fucine lake, compares the water of it to glass; a circumstance which shews the clear kinds of glass to have been well known in his time.

A. C. 36. Horace† is more express, and mentions glass in terms, that shew its clearness and brightness to have been brought to great perfection. In particular, he compares the fountain of Blandusia to glass, and says it was even brighter than that substance; an expression that carries great force, no glass at present possessing that quality, in a higher degree, than some spring waters.

Post Christum. A. D. 27. quo Strabo obiit. In the time of Strabo, the making of glass was undoubtedly well understood, and had become a great article of manufacture, as appears from the following account given by this author:

* Vitreâ te Fucinus undâ
Te liquidi flevere lacus.
Virg. Æneid. VII. 759.

† Perlucidior vitro. Hor. Carm. III. Ode II.
Splendidior vitro. Hor. Carm. III. Ode XIII.

" Between Ace, (or Ptolemais) and Tyre, the ſhore abounds with ſmall eminences, which are compoſed of a vitrifiable earth. They ſay, however, that it is not melted there, but brought to Sidon to undergo that operation. Some ſay, that the Sidonians have a vitrifiable ſand fit for fuſion; others ſay the ſand which is commonly found, is uſed for that purpoſe. I, myſelf, have heard (ſays Strabo) from the manufacturers of glaſs at Alexandria, that there is a certain vitrifiable earth in Egypt, without which, the moſt magnificent, and variouſly coloured pieces of manufacture cannot be made, as the different kinds of glaſs require different mixtures of ingredients. Many diſcoveries alſo were made at Rome, both with regard to the beauty of the colour, and alſo as to the facility of execution, eſpecially in thoſe kinds of glaſs that are made to reſemble chryſtal."

Seneca * was not only well acquainted with glaſs as a ſubſtance, but alſo underſtood its magnifying powers when formed into a convex ſhape. A. D. 65. Seneca Mors. A glaſs globe, ſays he, filled with water, makes letters viewed through it, appear larger and brighter. The magnifying power of glaſs conſidered as a more denſe, and of courſe a more refrangible medium than air, was not unknown

* Literæ quamvis minutæ & obſcuræ per vitream pilam aquâ plenam majores clarioreſque cernuntur.

Senec. Quæſt. Natur. I. 6.

to

to him. Fruits, * ſays he, viewed through glaſs, appear much larger, and more beautiful. The ſtars alſo appear magnified in a humid atmoſphere. If a ring be put into a bowl of water, and viewed there, it ſeems to approach to the eye, or in other words, is magnified; which the ſame author obſerves, is the caſe with every body that is viewed through a fluid. Seneca † ſays here expreſsly, that water, as a medium, has the ſame effect with glaſs. It is worthy remark, that the effect of the priſm in exhibiting the original colours that are combined in light, was a fact well known in the time of Seneca; and from his expreſſion, we may conjecture the experiment to have been frequently practiſed. " A rod of

* Poma per vitrum aſpicientibus multo majora ſunt.
Senec. Quæſt. Nat. I. 3.

† Poma formoſiora quam ſint videntur, ſi innatant vitro. Sidera ampliora per nubem aſpicienti videntur: quod acies noſtra in humido labitur, nec apprehendere quod vult fideliter poteſt. Quod manifeſtum fiet, ſi poculum impleveris aquâ, & in id conjeceris annulum. Nam cum in ipſo fundo jaceat annulus, facies ejus in ſummo aquæ redditur. Quicquid videtur per humorem longe amplius vero eſt. Quid mirum, majorem reddi imaginem Solis, quæ in nube humidâ viſitur, cum de cauſis duabus hoc accidat: quia in nube eſt aliquid vitro ſimile quod poteſt perlucere, eſt aliquid & aquæ, quam ſi nondum habet, tamen jam apparet ejus Natura, in quam ex ſuâ vertatur?
Senec. Quæſt. Natur. L. I. C. 6.

glaſs,* ſays he, is commonly made, drawn out, or ſwelling with many angles in form of a club: this, ſays he, if the rays of the ſun fall upon it in a tranſverſe direction, exhibits the ſame colours as we are accuſtomed to ſee in the rainbow." This curious paſſage has not been ſufficiently attended to by the commentators.

A. D. 66. Mors. Petronii.

Petronius Arbiter, in his account of the feaſt † of Trimalcio, makes him relate a ſtory of "an artificer, who could make veſſels of glaſs of ſuch a degree of tenacity as not to be more liable to be broken than if made of gold or ſilver. Having made a drinking cup of the pureſt glaſs of this kind, which he thought no one worthy to poſſeſs but the Emperor, he was admitted into his preſence, in order that he might offer this ſpecimen of his ingenuity for the Emperor's acceptance. The nature of his preſent met with praiſe; the hand of the artificer was commended, and the reſpect he ſhewed by it, found a favourable reception. The artiſt, however, being deſirous to heighten

* Virgula ſolet fieri vitrea, ſtricta, vel pluribus angulis in modum clavæ toroſa; hæc ſi ex tranſverſo ſolem accipit, colorem talem qualis in arcu videri ſolet, reddit.
Senec. Quæſt. Natur. Lib. I. Cap. 7.

† This paſſage from Petronius is to be found in Joannes Sariſburienſis.
Polycrat. L. IV. Cap. 5, and literally tranſlated.

their

their admiration into surprize and astonishment, and to conciliate more effectually the favour of the Emperor, requested the cup again from his hand; and having received it, threw it with all his force upon the pavement in so violent a manner, that it could not have escaped injury, had it been made of the most solid and uniform brass. The Emperor, at the sight of this action, was no less astonished than concerned; but the artist taking up the cup from the ground, which was not broken, but only bruised by the blow it received, which had the same effect upon it as it would have had if the cup had been made of copper; and drawing forth a hammer from his bosom, repaired the bruise that the glass had received, by hammering it with frequent strokes, much in the same way as if the cup had been of brass. The expectations of the artificer were much raised by the success of this operation, which had introduced him to the knowledge of the Emperor, and procured him general admiration; but the event turned out different from what he imagined; for the Emperor enquiring of him, if any one else was acquainted with the secret of preparing glass in such a manner; and he answering in the negative, his head was ordered to be struck off, the Emperor assigning for a reason, that if this secret should be made publick, gold and silver would lose their value, and become of no more estimation than clay."

It

It is difficult to guefs what the compofition of the fubftance here called glafs could be. It certainly could not be any vitrified body as fuch are univerfally brittle. Some have thought it to have been the luna cornea, or the calx of filver, made by the diffolution of that metal in the acid of nitre, and its precipitation by that of falt. But this, though endued with confiderable flexibility and tenacity, is not malleable to the degree here reprefented.

A. D. 77. Plinius obiit.

Pliny, however, appears to have left us the moft complete information concerning glafs. He mentions it as being of Phœnician origin, as many other great difcoveries have been. It was firft made of fand found in the river Belus, a fmall river of Galilee, running from the foot of Mount Carmel, out of the lake Cendevia. The part of the fhore where the fand was dug, did not exceed 500 paces in extent, and had been ufed many ages before, for the fame purpofe. The report of its difcovery was, that a merchant fhip laden with nitre, or foffil alkali, being driven upon the coaft, and the crew going afhore for provifions, and dreffing their victuals upon the fhore, made ufe of fome pieces of foffil alkali to fupport their kettles. By thefe means a vitrification of the fand beneath the fire was produced, which afforded a hint for the manufacture. In procefs of time the calx of iron, in form of the magnetical ftone,

came

came to be ufed along with the foffil alkali, from an idea of its not only containing iron, but glafs in a liquid form Clear pebbles, fhells, and foffil fand, were alfo in many places employed for the fame purpofe. It is faid, that in India, pieces of native chryftal were ufed for that purpofe; and on that account, the Indian glafs was preferred to any other: He adds, that light and dry woods were ufed for the melting of glafs; to which they added copper from the ifland of Cyprus, and the foffil alkali, efpecially that which is brought from the Eaft Indies. The furnaces are kept burning without intermiffion, that the copper may be melted with the glafs, and out of this compound are made maffes of a coarfe blackifh colour. Thefe lumps or maffes are again melted, and tinged of the colour required. Some of thefe pieces are brought to the fhape defired, by blowing it with the breath: fome are ground in a lathe, and others are emboffed in the fame manner with filver. Sidon was formerly famous for thefe manufactures, as fpecula or looking glaffes were firft invented there. The above is defcribed by Pliny, as the ancient method of making glafs. In his time, it was made with fand found at the mouth of the river Vulturnus, upon the fhore, for fix miles between Cumæ and the Lucrine Bay. This fand was very fine, and was ground to powder with a ball or fphere, and a mill

a mill. It was then mixed with three parts of the foſſil alkali, either by weight or meaſure; and being fuſed, was conveyed in a liquid ſtate into other furnaces, where it was formed into a maſs called ammonitrum (or ſand combined with the foſſil alkali), which maſs was melted, and became then pure glaſs, and a maſs of white vitrified matter. The ſame method of making it, prevailed in Spain and Gaul. Glaſs was likewiſe made to imitate the lapis obſidianus, a ſubſtance found by a perſon of the name of Obſidius, in Egypt and Æthiopia. It was of a very black colour, yet obſcurely tranſparent, and often placed among ſpecula, in the walls of rooms, to reflect the ſhadow of objects. It was alſo uſed for the ſame purpoſe as gems (I apprehend for engraving upon) and even for ſtatues, Pliny mentioning, that he ſaw ſolid ſtatues of the Emperor Auguſtus, made of this material; and the ſame Emperor dedicated four elephants made of the ſame ſubſtance in the Temple of Concord. It appears to have been uſed from great antiquity, ſince Tiberius Cæſar, when he governed that country, found a ſtatue of Menelaus, made of it. In the time of Pliny, the artificial imitation of it by glaſs, ſeems to have been in uſe inſtead of the native material. Pliny ſeems to intimate, that the black colour given to the glaſs that was made to imitate the lapis obſidianus, was pro-

duced

duced by ſome colouring ingredient.* But many ſtones commonly found, as the gray rag ſtone, the blue whin ſtone, the Derbyſhire toad ſtone, and the Weſtmoreland ſlate, will all melt into a vitreous maſs of a black colour. I was informed by his Grace the late Duke of Northumberland, whoſe knowledge in chemiſtry, and natural hiſtory, was very extenſive, that he once procured a pot of glaſs to be made at the Glaſshouſe at Newcaſtle upon Tyne, of the whin ſtone. The glaſs produced from it, was of a fine black colour, and good uniform texture, and eaſy fuſion; but inconvenient to be uſed for bottles, on account of its having ſcarcely any tranſparency. He likewiſe added, that it exactly reſembled ſome ſpecimens of what was imagined to be the ancient lapis obſidianus.

The Romans had likewiſe an opake red kind of glaſs, uſed for plates and diſhes for the table, called hæmatinon, one of various colours called myrrhinum, a white, a clear red, a blue, and indeed moſt other colours. Pliny obſerves of it, that no ſubſtance was more manageable in receiving colours, or being formed into ſhape than glaſs.

The perfectly clear glaſs, which bore the greateſt reſemblance to chryſtal, was, however, moſt valued. Nero gave for two cups, with two

* Plin. Hiſt. Nat. L. XXXVI. Cap. 26.

handles

handles to each, and of no extraordinary ſize, ſix thouſand ſeſtertia, or nearly fifty thouſand pounds ſterling. But although the finer kinds appear to have been ſo rare and valuable, the inferior kinds muſt have been not uncommon, ſince Pliny ſays, that the uſe of glaſs cups had nearly ſuperſeded thoſe of gold and ſilver.—Pliny likewiſe knew the power of a hollow glaſs globe, filled with water, in concentrating the rays of light, ſo as to produce flame in any combuſtible ſubſtance upon which the focus fell; and alſo mentions, that ſome ſurgeons in his time, made uſe of it as a cauſtic * for ulcers. He was likewiſe acquainted with the comparative hardneſs of gems and glaſs, as he obſerves, that the lapis obſidianus would not ſcratch the true gems; and † he alſo mentions the counterfeiting of the latter in his time, as a very lucrative art, and brought to great perfection. The ſame author mentions, that glaſs might be cut or engraven upon by means of diamonds, which art is evidenced by the antique gems ſo frequently found.

The ruins of the city of Pompeia, which was deſtroyed in the time of Pliny, have afforded examples of the uſe of glaſs in windows. I was informed by a gentleman of accuracy, that he had meaſured a pane of glaſs

A. D. 77.

* L. XXXVII. Cap. 2.

† L. XXXVII. Cap. 13.

found

found in a window there, and it amounted to eighteen inches long, by about fourteen wide.

A. D. 94. St. John the Evangelist.

The* inspired writer of the Apocalypse, describing the brightness of one of the appearances in his vision, calls it "a sea of glass, like unto chrystal."

A. D. 83. Josephus.

Josephus† the Jewish historian says, that "near the monument of Memnon, which lies on the river Belius in Galilee, there is a place an hundred cubits in extent, worthy admiration. It is (adds this writer) round and hollow; and although it be exhausted by the numerous ships that touch there, it is soon filled again; the winds as it were, by design, tearing up the white sand from other places, and bringing it hither, and the mine itself, has the power of changing the sand that is thus carried into it, into glass; and what seems to me more extraordinary, the glass that over-

* Θαλασσα υαλινη ομοια κρυσαλλω. Apoc. C. 4. V. 6.

† Του δε ασἶεως απο δυω ςαδιων ο καλουμενος Βηλεος ποταμος παραῤῥει πανταπασιν ολιγος, παρ ῷ το Μεμνονος μνημειον εσἶιν, εχον εγγυς αυτου τοπον εκατοντα πηχων θαυματος αξιον, κυκλοτερης μεν γαρ εσἶι και κοιλος, αναδιδωσι δε την υαλινην ψαμμον, ην οταν εκκενωση πολλα πλοια προσχοντα, παλιν αναπληρουται το χωριον κατασυροντων μεν ωσπερ επιτηδες τοτε των ανεμων εις αυτο την εξωθεν αργην ψαμμον, του δε μεταλλου πασαν ευθεως μεταβαλλοντος εις υαλον, θαυμασιωτερον τουτο μοι δοκειν, το την υπερχυθεισαν υαλον, παλιν γινεσθαι ψαμμον εικαιαν. Josph. L. II. C. 10.

flows

flows from this place, becomes again common ſand." It is evident, that Joſephus here, by the word υαλος, means only the ſand fit for the making of glaſs.

A. D. 84. Martial. In the time of Martial, glaſs was not only brought to great perfection, and in common uſe * for drinking veſſels, but was alſo employed (as it ſeems) for † bottles in which wine was kept, and likewiſe for ‡ pots to hold flowers.

A few words on the antiquity of the term (glaſs) may not in this place be improper. Tacitus and Pliny § inform us, that amber was called among the ancient Gauls and Germans, by the name of *gleſum* or *gleſſum*; and from the ſimilarity which glaſs bore to amber in point of

* Nos bibimus vitro, tu myrrha Pontice, quare?
Prodat perſpicuus ne duo vina calix.
Martial Epig. L. IV. Ep. 86.

† Condantur parco fuſca falerna vitro. L. II. Epig. 40.

‡ Condita ſic puro numerantur lilia vitro.
L. II. Epig. 22.

§ Succinum quod ipſi gleſſum vocant inter vada atque ipſo in litore legunt. *Taciti German.* C. 45.

Certum eſt gigni in inſulis ſeptentrionalis Oceani & a Germanis appellari gleſſum itaque & a noſtris unam inſularum ob id gleſſariam appellatam.
Plin. Hiſt. Nat. Lib. XXXVII. Cp. 3.

transparency

transparency and brightness,* it acquired a name which was in all probability, originally the same.

The word *glesum* implied no doubt a shining or transparent substance; *gleissen* expresses at present in the German language, to shine; and our English word to *glisten* is derived from it, and has nearly the same signification. Du Cange ‡ says, that some critics were of opinion, that the word *glesum* itself, implied glass rather than amber. It is farther remarkable, that the ancient Greeks applied the same term (Ηλεκτρον), || both to glass and amber.

The herb wherewith the Britons painted their bodies, went also under the name of

* Antiquis Germanis fuisse *glessum* auctores sunt Plinius atque Tacitus quamquam apud hunc perperam legitur *glesum* unico s nam ipsis Germanis fuit *gless* quo vocabulo postea paulum variato in *glass* vitrum quum id novum atque antea inusitatum Germaniæ inferretur interpretati sunt ob similitudinem quandam

Cluverii Germania Antiq. L. III. Cap. 44.

Inde hodie fortasse vitrum glassum appellant nam succinum vitream habet perspicuitatem.

Salmas. Comm. in Solin. p. 165.

‡ Censent quidam *glessum* nihil aliud esse quam quod Anglo Saxones ʒlæɼ Galli, Germani & Angli *glase* vocant.

Du Cange Gloss Vox Glessum.

|| Certe Ηλεκτρε mentio apud Homerum non Υαλου.

Salmas. Plin. Exerc. p. 773.

Homero & aliis antiquis nomen Υαλος notum non fuisse sed pro eo Ηλεκτρος dici. Budæi Lexicon Vox Ηλεκτρον.

 glastum,

glaſtum,* perhaps from the ſhining appearance it might give to their ſkins, or poſſibly becauſe its aſhes might be uſed in the making of glaſs. The Romans called the ſame plant by the name of *vitrum* †, the word they uſed to ſignify glaſs.

A. D. 143. Galen.

Galen makes mention of glaſs in ſeveral parts of his works. ‡ He appears to be well acquainted with it, and the method of making it. He tells us, that it was made from ſand melted in furnaces, which was required to be pure, ſince if any metallic ſubſtance was mixed therewith, the glaſs was ſpoiled. Thoſe concerned in the manufacture, knew by looking at the ſand if it was fit for this purpoſe. In other places, he adviſes medicines of a corroſive nature to be kept in glaſs veſſels, as ſuch are not liable to be corroded, or to impart any bad qualities. Glaſs was alſo uſed for cupping glaſſes in his time, much in the ſame way as at preſent.

* Simile plantagini *glaſtum* in Gallia vocatur, quo Britannorum conjuges nuruſque, toto corpore oblitæ, quibuſdam in ſacris & nudæ incedunt, Æthiopum colorem imitantes.
Plin. Lib. XXII. Cap. 1.

† Omnes vero ſe Britanni *vitro* inficiunt quod cæruleum efficit colorem, Cæſ. Bell. Gall. L. V.

‡ De Simpl. Medicam. facultate. Lib. IX. De Terrâ Samia. De Antidotis. Lib. VIII. Cap. 8. De compos Pharm. ſecund. loc. L. VIII. Cap. 5.

Apuleius

A. D. 161. Apuleius.

Apuleius mentions the manufactory of glaſs cups in his time, as highly worked and carved in various ways, and of great value.

A. D. 214. Alexander Aphrodiſienſis.

Alexander Aphrodiſienſis, a Greek writer, and a commentator on Ariſtotle, has ſeveral remarks on glaſs * relative both to its brittleneſs, eſpecially on change of temperature, and its tranſparency.

The manufacturers of glaſs ſeem to have been erected into a kind of Company at Rome, and to have had a ſtreet aſſigned them, which was in the firſt region or diviſion of the city, near the Porta Capena. †

A. D. 220.

A tax was laid upon them by Alexander Severus, ‡ which ſubſiſted in the time of Aurelian, ‖ and probably long after.

The firſt author that I find, who makes mention of glaſs in windows, though there is no

* *Αι υελοι εν τω χειμωνι θερμου σφοδρα τινος εμβληθεντος ρηγνυνται.* Alex. Aphrod. probl. I.

Ωσπερ δι υελου εμφαινει το ευανθες του χρωματος. Alex. Aphrod. ex. Steph. Theſaur. Græc. vox Υαλος.

† Sextus Rufus in deſcript. urb. Romæ.

‡ Ælii Lampr. Alex. Severus.

‖ Vopiſcus Aurelianus.

doubt it was in uſe for this purpoſe
A. D. 320 Lactantius. before, is Lactantius, * who ſpeaks in expreſs terms of glaſs being uſed as a tranſparent ſubſtance in windows, for which it appears to have been in common uſe together with the lapis ſpecularis.

A. D. 422. Hieronymus obiit. Æt. 91. St. Jerome † likewiſe ſpeaks of glaſs windows formed of glaſs, melted and caſt into thin plates, being in uſe in his time.

A. D. 534. Paulus Silentiarius. Paulus Silentiarus, ‡ a poet and hiſtorian of the ſixth century, who wrote in verſe a deſcription of the church of Sancta Sophia at Conſtantinople, ſpeaks of the brightneſs of the ſun's rays at its riſe, coming through the eaſtern windows of that church, which were covered with glaſs.

* Manifeſtius eſt mentem eſſe quæ per oculos ea quæ ſunt oppoſita tranſpiciat, quaſi per feneſtras lucenti vitro aut ſpeculari lapide obductas.

Lactant De Opific Dei. Cap. 5.

† Vitrearum feneſtrarum mentio apud Hieronymum quæ vitro in tenues laminas fuſo obductæ erant.

Salm. Plin. Exerc. p. 771.

‡ ———————— δοχεια φωτος ανοιγει,
Λεπταλεαις υελοις κεκαλυμμενα, των δια μεσσης,
Φαιδρον αναστραπτουσα φαεσφορος ερχεται ηως.

Gregory

A. D. 571 Gregory of Tours.

Gregory of Tours* tir cribing the ravages of war, make quent mention of the devastations committed on the windows of the churches.

A. D. 571. Fortunatus.

Fortunatus † likewise, who was contemporary with Gregory of Tours, and also bishop of Tours and Poictiers, wrote a poem on the church at Paris, where he describes the light coming through the glass windows, as one of the principal circumstances that contributed to its beauty and ornament.

A. D. 630. Johannes Philoponus.

Johannes Philoponus ‡ the philosopher, who lived according to Helvicus, about the year 630, but according to Hoffman, a century earlier, not only speaks of glass, but of the panes being fastened in with plaister, much in the same way as at present.

* Ascendentes per eum, effracta vitrea ingressi sunt.
Gregor. Turon. Lib. VI. C. 10.

Effractis cellulæ vitreis hastas per parietis fenestras injiciunt. Ibid. L. VII. C. 29.

Si aliud inquit invenere non possum vel has ipsas quas cerno *vitreas* anferam. Lib. I. Miracul. C. 29.

† Prima capit radios vitreis oculata fenestris,
Atificisq. manu clausit in arce diem.
Fortunatus. Lib. II. Poem 11. De Eccles. Parisiac.

‡ Λαμπτηρας ποιει η τα υελια α δια της γυψηπλα σ[illegible] τεχνης επιτιθειται ταις οικιας χαριν του φωτιζεσθαι ταυτας. Phil. 11. post Analecta citat a Salm. Plin. Exerciet, 771.

A. D. 651. St. Audoen.

St. Audoen the biſhop of Rouen, in his hiſtory of the life of his contemporary St. Eligius, the biſhop of Noyon, * mentions a miraculous appearance in form of an arch or bow, about the great glaſs windows of a certain church.

A. D. incert.

The venerable Bede † relates alſo, that about the middle of this century, the art of making glaſs was brought into England by Benedict an Eccleſiaſtic, the miniſter of Oſway, the king of Northumberland.

A. D. 726. Wigfred biſhop of Worceſter.

Thomas Stubbs, however, in his account of the prelates that have ſucceeded to the See of York, ſays, that Wigfrid, biſhop of Worceſter, ‡ brought firſt into Britain the art of making glaſs windows, which is inconſiſtent with what is related by Bede.

A. D. 760. Leo Oſtienſis.

Leo Oſtienſis ‖ ſpeaks of the windows in his time being made with glaſs plates fixed in lead, and faſtened

* Apparuit ſubito in pariete circa vitroam maximam veluti arcus in rotundo. Vita Sanct. Eligii. Lib. II. Cap. 45.

† Chronicon Ranulphi. Higdeni. Ed. Gale. Vol. I. p. 235.

‡ Vide etiam Bedam de Wiremuthenſe monaſterio. L. I. C. 5. de vitreis feneſtris.

‖ Feneſtras plumbo ſimul ac vitro compactis tabulis ferreque connexis incluſit. Leo. Oſt. L. III.. C 27.

together

together with iron, much as we see them at present.

A. D. 800. Anastasius. Anastasius * an historian of Rome, who was librarian to the Pope, mentions, that in the Pontificate of Leo III. who became Pope about the year 800, painted glass in windows was in use. The same

A. D. 850. writer describes four large glass ornaments of the pensile kind, that were hung up in the church of St. Clement the martyr, weighing fifty pounds.

A. D. 1156. The statutes of the church of Traguier,† in Lower Britany, in the 12th century, speak of the windows of churches and chapels being ornamented with arms, and military ensigns, painted upon the glass in them.

* Hoffm. Lexic. Vox Fenestra.

. Idem fecit prædictus præsul in Ecclesia beati Clementis Martyris atque Pontificis, Regnum quod pendet supra altare majus ex auro purissimo sculptile sine gemmis habens in medio crucem de Auro cum gemmis fixis in eadem cruce. Vitreas quinque & quæ pendent item Vitreas numero quatuor pensantes libras quinquaginta.

Anast. in Vitâ Leonis IV.

† Qui fenestras ecclesiarum & capellarum dictarum nostrarum civitates & diocesis aliquando devotione aliquando ambitione & superbia vitrare & vitris hujus modi arma & signa depingi faciunt prætenduntque per appositionem & picturam armorum & signorum hujus modi vitra memorata, &c. Stat. Ecclef. Trecor. A. D. 1156.

A. D. 1156. Sugerius * abbot of St. Denys, the minifter of Lewis VII. fpeaks of a glafs window being prefented to the church at Paris, by Barbedaurus the dean, that coft fifteen pounds, which is upwards of 47 pounds fterling intrinfic value, exclufive of the alteration occafioned by the prefent relative plenty of money.

A. D. 1309. It appears from a charter in the beginning of the fourteenth century, that a glafs cup was then valued at a denarius, ‡ or about threepence halfpenny fterling, intrinfic value, exclufive of the alteration in the relative value refpecting the prefent time.

A. D. 1338. † A fhort time afterwards, there appears a charter of ftipulation for the erection of a glafs-houfe, to be kept up conftantly and worked.

* Obiit Barbedaurus Decanus & Sacerdos qui fecit fieri vitream quindecim libris comparatam.

Suger Lib. De Admir. fua. Cap. 29.

‡ Item a quolibet verrerio exponente vitros fuos ad vendendum levatur unus vitrus vel unus denarius quod verrerius maluerit. Du Cange Vox Verrerius.

† Pactis infra fcriptis videlicet quod infra dictum nemus dictus Guionetus faciat domum fortem & ibidem debeat habitare & verreriam ibidem facere tenere & operari facere in ea perpetuo opus vitrorum five vitrei.

Du Cange Vox Verreria.

In

A. D. 1364. * In the year 1364, there was a ſtreet in Paris, called from this manufactory.

† A charter of Richard II. of England, A. D. 1386. quoted by Rymer, about the ſame period, ſpeaks of glaſs, and the manufactures of it for windows.

* Tranſtulerunt domino dicto regi unam domum ſitam Pariſii in vico vitreriæ. Du Cange Vox Vitreria.

† Cum quædam capella reparanda exiſtat ac de vitro & vitriatoribus pro reparatione feneſtrarum & aliorum locorum ejuſdem capellæ multipliciter indigeat.

Rymer's Fæd. Tom. VII. p 527.

On

On the DIFFERENT QUANTITIES *of* RAIN *which* FALL, *at* DIFFERENT HEIGHTS, *over the ſame* SPOT *of* GROUND, *with a* LETTER *from* BENJAMIN FRANKLIN, LL. D. *By* THOMAS PERCIVAL, M. D. *&c. Read January* 21, 1784.

IT is a reflection which may mortify pride and humble arrogance, but ought certainly to animate the ſpirit of patient attention, and conſole us under the diſappointments of philoſophical purſuits, that many of the moſt intereſting laws of nature have remained undiſcovered, till ſome happy coincidence of circumſtances hath pointed them out to inquiry or obſervation. Thus the energy of fire muſt have been known and felt from the creation of the world; but the regularity of the expanſile power, on different bodies, is a modern diſcovery, of uncertain date. And the real nature of this ſubtile element, which pervades and actuates all matter, and is continually perceptible to our ſenſes, is yet but imperfectly explored. The ancients were acquainted with the magnifying power of *denſe mediums*; and Seneca has noticed, that ſmall letters appear larger and brighter when viewed through a glaſs globe filled with water. He has remarked, alſo, that apples are more beautiful,

beautiful, when ſwimming in ſuch a veſſel. But theſe obſervations, which muſt have been made by numberleſs ſpectators, in a long ſucceſſion of years, were regarded as ſolitary facts; and it was not till the thirteenth century, that ſpectacles were conſtructed, in conſequence, probably, of the experiments made by the Arabian philoſopher Alhazen, and our juſtly celebrated countryman Roger Bacon. Yet though magnifying glaſſes came then into general uſe, and muſt have been daily handled by artiſts and others, three hundred years elapſed before it occurred to any one to put them together, ſo as to form a teleſcope. The collection of watery vapours in the air, the figures of clouds, and the deſcent of rain, could paſs in no age unnoticed by mankind, and have long been the ſubjects of attentive inveſtigation. Yet it is a very recent diſcovery, which we owe to the ſagacity of a moſt ingenious phyſician and philoſopher, that a manifeſt difference ſubſiſts in the quantity of rain which falls, at different heights, over the ſame ſpot of ground.

A compariſon having been made between the rain which fell in two places, in London, about a mile diſtant, it was found that the quantity in one of them conſtantly exceeded that in the other, not only every month, but almoſt every time it rained. The apparatus uſed was very exact; and this unexpected variation did not

appear

appear to be owing to any miſtake, but to be the regular effect of ſome cauſe, hitherto unnoticed. The rain-gage, in one of theſe places, was fixed above all the neighbouring chimnies; the other was conſiderably below them: and there was reaſon to ſuſpect, that the difference in the quantity of rain, might be owing to the different ſituations of the veſſels, in which it was received. A funnel was, therefore, placed above the higheſt chimnies, and another upon the ground of the garden, belonging to the ſame houſe; and the like diverſity was found between the two, thus near together, which had ſubſiſted, when they were fixed, at correſpondent heights, in different parts of the town. Similar experiments were made on Weſtminſter Abbey;* and repeated at Bath, Liverpool, Middlewich, and other places, with nearly uniform reſults. The obſervations, therefore, however new and ſingular, are too well authenticated, to admit of the leaſt degree of doubt: and it is the office of philoſophy to furniſh an adequate and rational ſolution of them. Dr. Heberden conjectures that the phænomenon depends on ſome *unknown* property of electricity. To me it appears probable that the common laws, by which this power influences the aſcent and ſuſpenſion of vapours, are ſufficient to explain their precipitation in rain, and

* Phil. Tranſact. vol. LIX. p. 359.

the

the lately difcovered mode of its defcent. And in a Memoir,* written fome time ago, I endeavoured to prove, that the electrical fluid is ftrongly attracted by water; and that by deftroying the cohefion between its particles, and repelling them from each other, it becomes a powerful agent in evaporation, and in the formation of clouds. Thus when two clouds, containing different portions of electric fire, come within the fphere of mutual attraction, they will rufh together, and the electrical fluid, being diffufed through a larger fpace, the particles of water will unite, and forming themfelves into drops, a fhower will be produced: that as the rain defcends, through an atmofphere containing little electric fire, it will be continually communicating it; the drops will coalefce more and more together, by the progreffive diminution of the power which counteracts their mutual attraction; and confequently, in a given fpace, a much larger quantity will fall near to, than at a diftance from the furface of the earth. And, laftly, that to this effect the precipitation of the vapours, contained in a diffolved or diffufed ftate, in the lower regions of the atmofphere will, in fome degree, contribute: for it has been obferved to be fair, upon the top of the Cathedral

* See the author's Philofophical, Medical and Experimental Effays, vol. III. p. 112.

at

at York, at the time when there were ſmall drizzling rains, with thick miſts, in the ſtreets below.*

The Memoir, of which I have here given a brief view, was diſtributed amongſt my literary correſpondents, and procured me many curious and intereſting obſervations on the ſubject. And, I truſt, my friend Dr. Franklin will forgive the liberty I take, in communicating, to the ſociety, the following letter, with which I was honoured by him, on this occaſion. The opinions and conjectures of ſo eminent a philoſopher may, almoſt, be deemed common property; and on the point in queſtion, they are of peculiar value and authority.

Extract of a Letter from BENJAMIN FRANKLIN, L.L.D. &c. *to Dr.* PERCIVAL.

"ON my return to London I found your favour, of the ſixteenth of May (1771). I wiſh I could, as you deſire, give you a better explanation of the phænomenon in queſtion, ſince you ſeem not quite ſatisfied with your own; but I think we want more and a greater variety of experiments in different circumſtances, to enable us to form a thoroughly ſatisfactory hypotheſis.

* Hunter's Georgical Eſſays, p. 112.

Not

Not that I make the leaſt doubt of the facts already related, as I know both Lord Charles Cavendiſh, and Dr. Heberden to be very accurate experimenters: but I wiſh to know the event of the trials propoſed in your ſix queries; and alſo, whether in the ſame place where the lower veſſel receives nearly twice the quantity of water that is received by the upper, a third veſſel placed at half the height will receive a quantity proportionable. I will however endeavour to explain to you what occurred to me, when I firſt heard of the fact.

I ſuppoſe, it will be generally allowed, on a little conſideration of the ſubject, that ſcarce any drop of water was, when it began to fall from the clouds, of a magnitude equal to that it has acquired, when it arrives at the earth; the ſame of the ſeveral pieces of hail; becauſe they are often ſo large and weighty, that we cannot conceive a poſſibility of their being ſuſpended in the air, and remaining at reſt there, for any time, how ſmall ſoever; nor do we conceive any means of forming them ſo large, before they ſet out to fall. It ſeems then, that each beginning drop, and particle of hail, receives continual addition in its progreſs downwards. This may be ſeveral ways: by the union of numbers in their courſe, ſo that what was at firſt only a deſcending miſt, becomes a ſhower; or by each particle in its deſcent through air that contains

a great

a great quantity of diſſolved water, ſtriking againſt, attaching to itſelf, and carrying down with it, ſuch particles of that diſſolved water, as happen to be in its way; or attracting to itſelf ſuch as do not lie directly in its courſe, by its different ſtate with regard either to common or electric fire; or by all theſe cauſes united.

In the firſt caſe, by the uniting of numbers, larger drops might be made, but the quantity falling in the ſame ſpace would be the ſame at all heights; unleſs, as you mention, the whole ſhould be contracted in falling, the lines deſcribed by all the drops converging, ſo that what ſet out to fall from a cloud of many thouſand acres, ſhould reach the earth in perhaps a third of that extent, of which I ſomewhat doubt. In the other caſes we have two experiments.

1. A dry glaſs bottle, filled with very cold water, in a warm day, will preſently collect from the ſeemingly dry air that ſurrounds it, a quantity of water that ſhall cover its ſurface and run down its ſides, which perhaps is done by the power wherewith the cold water attracts the fluid, common fire that had been united with the diſſolved water in the air, and drawing that fire through the glaſs into itſelf, leaves the water on the outſide.

2. An electrified body left in a room for ſome time, will be more covered with duſt than other bodies in the ſame room not electrified, which

which duſt ſeems to be attracted from the circumambient air.

Now we know that the rain, even in our hotteſt days, comes from a very cold region. Its falling ſometimes in the form of ice, ſhews this clearly; and perhaps even the rain is ſnow or ice when it firſt moves downwards, though thawed in falling: and we know that the drops of rain are often electrified: but thoſe cauſes of addition to each drop of water, or piece of hail, one would think could not long continue to produce the ſame effect; ſince the air, through which the drops fall, muſt ſoon be ſtript of its previouſly diſſolved water, ſo as to be no longer capable of augmenting them. Indeed very heavy ſhowers, of either, are never of long continuance; but moderate rains often continue ſo long as to puzzle this hypotheſis: So that upon the whole I think, as I intimated before, that we are yet hardly ripe for making one."

Speculations *on the* Perceptive Power *of* Vegetables. *By* Thomas Percival, M. D. F. R. S. *&c. &c.* *Read February* 18, 1784.

> - - - - Thefe are not idle, philofophic dreams;
> Full Nature *teems* with life. - - - -
>
> Thomson's Spring, Second Edit. line 136.*

IN all our enquiries into truth, whether natural or moral, it is neceffary to take into previous confideration, the kind of evidence which the fubject admits of; and the degree of it, which is fufficient to afford fatisfaction to the mind. Demonftrative evidence is abfolute, and without gradation; but probable evidence afcends, by regular fteps, from the loweft prefumption, to the higheft moral certainty. A fingle prefumption is, indeed, of little weight; but a feries of fuch imperfect proofs may produce the fulleft conviction. The ftrength of belief, however, may often be greater, than is proportionate to the force and number of thefe proofs, either individually or collectively confidered. For, as uncertainty is always painful to the underftanding, very flight evidence, if the fubject

* Thefe lines are omitted in the fubfequent editions of Thomfon's Seafons.

be

be capable of no other, ſometimes amounts to credibility. This every philoſopher experiences, in his reſearches into nature; and the obſervation may ſerve as an apology for the following *jeu d'eſprit*; in which I ſhall attempt to ſhew, by the ſeveral analogies of organization, life, inſtinct, ſpontaneity, and ſelf-motion, that plants, like animals, are endued with the powers, both of perception and enjoyment.

I. Vegetables bear ſo near a ſimilitude to animals in their STRUCTURE, that botaniſts have derived from anatomy and phyſiology, almoſt all the terms employed in the deſcription of them. A tree or ſhrub, they inform us, conſiſts of a cuticle, cutis, and cellular membrane; of veſſels variouſly diſpoſed, and adapted to the tranſmiſſion of different fluids; and of a ligneous, or bony ſubſtance, covering and defending a pith or marrow. Such organization evidently belongs not to inanimate matter; and when we obſerve, in vegetables, that it is connected with, or inſtrumental to the powers of growth, of ſelf-preſervation, of motion, and of ſeminal increaſe, we cannot heſitate to aſcribe to them a LIVING PRINCIPLE. And by admitting this attribute, we advance a ſtep higher in the analogy we are purſuing. For, the idea of life naturally implies ſome degree of perceptivity: And wherever perception reſides, a greater or

 leſs

lefs capacity for enjoyment feems to be its neceffary adjunct. Indefinite and low, therefore, as this capacity may be, in each fingle herb or tree, yet, when we confider the amazing extent of the vegetable kingdom, "from the cedar of Lebanon to the hyffop upon the wall," the aggregate of happinefs, produced by it, will be found to exceed our moft enlarged conceptions. It is prejudice only, which reftrains or fuppreffes the delightful emotions, refulting from the belief of fuch a diffufion of good. And, becaufe the framers of fyftems have invented arrangements and divifions of the works of God, to aid the mind in the purfuits of fcience, we implicitly admit as reality, what is merely artificial; and adopt diftinctions, without proof of any effential difference. *Lapides crefcunt; vegetabilia crefcunt et vivunt; animalia crefcunt, vivunt, et fentiunt.* This climax, of Linnæus, is conformable to the doctrines of Ariftotle, Pliny, Jungius, and others: But none of thefe great men have adduced fufficient evidence, to fupport the negative characteriftics, if I may fo exprefs myfelf, on which the three kingdoms of nature are here eftablifhed. That a gradation fubfifts, in the fcale of beings, is clearly manifeft; but the higher advances we make in phyfical knowledge, the nearer will the degrees be feen to approach each other. And it is no very extravagant conjecture to fuppofe, that, in fome future period, perceptivity may

may be difcovered to extend, even beyond the limits now affigned to vegetable life. Corallines, madrepores, millepores, and fpunges were formerly confidered as foffil bodies: but the experiments of Count Marfigli evinced, that they are endued with life, and led him to clafs them with the maritime plants. And the obfervations of Ellis, Juffieu and Peyfonel, have fince raifed them to the rank of animals.* The detection of error, in long eftablifhed opinions concerning one branch of natural knowledge, juftifies the fufpicion of its exiftence in others, which are nearly allied to it: And it will appear, from the profecution of our enquiry into the inftincts, fpontaneity, and felf-moving power of vegetables, that the fufpicion is not without foundation.

II. Instinct is a propenfity, or movement to feek, without deliberation, what is agreeable to the particular nature, actuated by it; and to avoid what is incongruous or hurtful. It is a practical power, which requires no previous knowledge or experience; and which purfues a prefent or future good, without any definite ideas or forefight; and often, with very faint degrees of confcioufnefs. The calf, when it firft comes into the world, applies to the teats of the cow, utterly ignorant of the tafte, or nutritious quality of the milk, and confequently,

* Confult Philof. Tranfact. Amænitat. Academic. and Bifhop Watfon on the Subjects of Chemiftry.

with no views, either to ſenſual gratification, or ſupport: And the duckling, which has been hatched under a hen, at a diſtance from water, diſcovers a conſtant reſtleſsneſs and impatience; and is obſerved to practiſe all the motions of ſwimming, though a ſtranger to its future deſignation, and to the element, for which its oily feathers, and web-like feet, are formed. Inſtincts analogous to theſe, operate with equal energy, on the vegetable tribe. A ſeed contains a *germ*, or plant in miniature, and a *radicle*, or little root, intended by nature to ſupply it with nouriſhment. If the ſeed be ſown in an inverted poſition, ſtill each part purſues its proper direction. The *plumula* turns upward, and the *radicle* ſtrikes downward, into the ground. A hop-plant, turning round a pole, follows the courſe of the ſun, from ſouth to weſt, and ſoon dies, when forced into an oppoſite line of motion: But remove the obſtacle, and the plant will quickly return to its ordinary poſition. The branches of a honey ſuckle ſhoot out longitudinally, till they become unable to bear their own weight; and then ſtrengthen themſelves, by changing their form into a ſpiral: When they meet with other living branches, of the ſame kind, they coaleſce, for mutual ſupport, and one ſpiral turns to the right, and the other to the left; thus ſeeking, by an inſtinctive impulſe, ſome body on which to climb, and increaſing the

the probability of finding one, by the diverſity of their courſe: For if the auxiliary branch be dead, the other uniformly winds itſelf round, from the right to the left.*

Theſe examples, of the inſtinctive œconomy of vegetables, have been purpoſely taken from ſubjects, familiar to our daily obſervation. But the plants of warmer climates, were we ſufficiently acquainted with them, would probably furniſh better illuſtrations of this acknowledged power of animality: And I ſhall briefly recite the hiſtory of a very curious exotic, which has been delivered to us from good authority; and confirmed by the obſervations of ſeveral European botaniſts.

The Dionæa Muſcipula is a native of North Carolina. Its leaves are numerous, inclining to bend downwards, and placed in a circular order: they are jointed, and ſucculent: The upper joint conſiſts of two lobes, each of which is ſemi-oval in its form, with a margin furniſhed with ſtiff hairs; which embrace each other, when they cloſe from any irritation. The ſurfaces of theſe lobes are covered with ſmall red glands, which probably ſecrete ſome ſweet liquor, tempting to the taſte, but fatal to the lives of inſects: For, the moment the poor animal alights upon theſe parts, the two lobes riſe up,

* Lord Kaims's Gentleman Farmer.

grafp it forcibly, lock the rows of fpines together, and fqueeze it to death: And, left the ftruggles for life fhould difengage the infect, thus entangled, three fmall fpines are fixed amongft the glands, near the middle of each lobe, which effectually put an end to all its efforts: nor do the lobes open again, while the dead animal continues there. The diffolution of its fubftance, therefore, is fuppofed, by naturalifts, to conftitute part of the nourifhment of the plant. But as the difcriminative power of inftinct is always limited, and proceeds with a blind uniformity when put into exertion, the plant clofes its leaves as forcibly, if ftimulated by a ftraw or a pin, as by the body of an infect: Nor does it expand them again, till the extraneous fubftance is withdrawn.*

III. If the facts and obfervations, which have been adduced, furnifh any prefumptive proof of the inftinctive power of vegetables, it will neceffarily follow, that they muft be endued with fome degree of SPONTANEITY. For the impulfe to difcriminate and to prefer, is an actual exertion of that principle, however obfcure the confcioufnefs or the feeling may be, with which it is accompanied: And fuch volition prefuppofes an innate perception, both of what is confonant, and of what is injurious to the conftitution of the individual, or fpecies directed by it. But

* See the Annual Regifter for 1775, p. 93.

it

it is the defign of this little Effay, rather to inveftigate nature, than to appeal to metaphyfical confiderations: I fhall proceed, therefore, to point out a few of thofe phenomena, in the vegetable kingdom, which indicate fpontaneity.

Several years ago, whilft engaged in a courfe of experiments to afcertain the influence of fixed air on vegetation, the following fact repeatedly occurred to me. A fprig of mint, fufpended by the root, with the head downwards, in the middle glafs veffel of Dr. Nooth's machine, continued to thrive vigoroufly, without any other pabulum, than what was fupplied by the ftream of mephitic gas, to which it was expofed. In twenty-four hours, the ftem formed into a curve, the head became erect, and gradually afcended towards the mouth of the veffel; thus producing, by fucceffive efforts, a new and unufual configuration of its parts. Such exertions in the fprig of mint, to rectify its inverted pofition, and to remove from a foreign, to its natural element, feems to evince volition to avoid what was evil, and to recover what had been experienced to be good. If a plant, in a garden-pot, be placed in a room, which has no light, except from a hole in the wall, it will fhoot towards the hole, pafs through it into the open air, and then vegetate upwards, in its proper direction. Lord Kaims relates, that, "amongft the ruins of New Abbey, formerly a "monaftery

"monaſtery in Galloway, there grows on the
"top of a wall, a plane tree, twenty feet high.
"Straitened for nouriſhment, in that barren
"ſituation, it ſeveral years ago directed roots
"down the ſide of the wall, till they reached
"the ground, ten feet below: And now, the
"nouriſhment it afforded to theſe roots, during
"the time of deſcending, is amply repaid; hav-
"ing every year, ſince that time, made vigorous
"ſhoots. From the top of the wall, to the ſur-
"face of the earth, theſe roots have not thrown
"out a ſimple fibre, but are now united into a
"pretty thick hard root."*

The regular movements, by which the ſun-flower preſents its ſplendid diſk to the ſun, have been known to naturaliſts, and celebrated by poets, both of ancient and modern times. Ovid founds upon it a beautiful ſtory; and Thomſon deſcribes it as an attachment of love, to the celeſtial luminary.

"But one, the lofty follower of the ſun,
"Sad when he ſets; ſhuts up her yellow leaves,
"Drooping all night; and when he warm returns,
"Points her enamour'd boſom to his ray."

Summer, line 216.

IV. Nature has wiſely proportioned the POWERS OF MOTION, to the diverſified neceſſities of the beings endued with them. Corallines and Seapens are fixed to a ſpot, becauſe all their

* Gentleman Farmer.

wants

wants may be there ſupplied. The oyſter, during the afflux of the tide, opens to admit the water, lying with the hollow ſhell downwards: But when the ebb commences, it turns on the other ſide; thus providing, by an inconſiderable movement, for the reception of its proper nutriment; and afterwards diſcharging what is ſuperfluous.* Mr. Miller, in his late account of the iſland of Sumatra, mentions a ſpecies of coral, which the inhabitants have miſtaken for a plant, and have denominated it Lalan—Cout, or ſea-graſs. It is found in ſhallow bays, where it appears like a ſtraight ſtick, but when touched, withdraws itſelf into the ſand.† Now, if ſelf-moving faculties, like theſe, indicate animality, can ſuch a diſtinction be denied to vegetables, poſſeſſed of them in an equal, or ſuperior degree? The water-lily, be the pond deep or ſhallow in which it grows, puſhes up its flower-ſtems, till they reach the open air, that the farina fecundans may perform, without injury, its proper office. About ſeven in the morning, the ſtalk erects itſelf, and the flowers riſe above the ſurface of the water: In this ſtate they continue till four in the afternoon, when the ſtalk becomes relaxed, and the flowers ſink and cloſe. The motions of the ſenſitive plant have been long

* Sprat's Hiſtory of the Royal Society.

† Philoſph. Tranſact. vol. LXVIII. p. 178.

noticed

noticed with admiration, as exhibiting the moſt obvious ſigns of perceptivity. And if we admit ſuch motions, as criteria of a like power, in other beings, to attribute them, in this inſtance, to mere mechaniſm, actuated ſolely by external impulſe, is to deviate from the ſoundeſt rule of philoſophizing, which directs us not to multiply cauſes, when the effects appear to be the ſame. Neither will the laws of electricity better ſolve the phenomena of this animated vegetable: For its leaves are equally affected by the contact of electric, and non-electric bodies; ſhew no change in their ſenſibility, whether the atmoſphere be dry or moiſt; and inſtantly cloſe when the vapour of volatile alkali, or the fumes of burning ſulphur are applied to them. The powers of chemical ſtimuli, to produce contractions in the fibres of this plant, may perhaps lead ſome philoſophers, to refer them to the *vis inſita*, or irritability, which they aſſign to certain parts of organized matter, totally diſtinct from, and independent of, any ſentient energy. But the hypotheſis is evidently a ſoleciſm, and refutes itſelf. For the preſence of irritability can only be proved by the experience of irritations, and the idea of irritation involves in it that of feeling.

But there is a ſpecies of the order of Decandria, which conſtantly and uniformly exerts a ſelf-moving power, uninfluenced either by chemical ſtimuli, or by any external impulſe whatſoever.

This

This curious ſhrub, which was unknown to Linnæus, is a native of the Eaſt Indies, but has been cultivated in ſeveral botanical gardens here. I had an opportunity of examining it, in the collection of the late Dr. Brown. It is trifolious, grows to the height of four feet, and produces, in autumn, yellow flowers. The lateral leaves are ſmaller than thoſe at the extremity of the ſtalk; and all day long, they are continually moving either upwards, downwards, or in the ſegment of a circle: The laſt motion is performed by the twiſting of the foot ſtalks; and whilſt one leaf is riſing, its aſſociate is generally deſcending: The motion downwards is quicker and more irregular, than the motion upwards, which is ſteady and uniform. Theſe movements are obſervable, during the ſpace of twenty-four hours, in the leaves of a branch lopped off from the ſhrub, and kept in water. If, from any obſtacle, the motion be retarded, upon the removal of that obſtacle, it is reſumed with a greater degree of velocity.* I cannot better comment on this wonderful degree of vegetable animation, than in the words of Cicero. *Inanimum eſt omne quod pulſu agitatur externo; quod autem eſt animal, id motu cietur interiore et ſuo.*

I have thus attempted, with the brevity preſcribed by the laws of this Society, to extend

* See Encyclopædia Britannica, Art. Hedyſarum.

our

our views of animated nature; to gratify the mind with the contemplation of multiplied acceſſions to the general aggregate of felicity; and to exalt our conceptions of the wiſdom, power, and beneficence of God. In an undertaking, never yet accompliſhed, diſappointment can be no diſgrace: In one, directed to ſuch noble objects, the motives are a juſtification, independently of ſucceſs. Truth, indeed, obliges me to acknowledge, that I review my ſpeculations with much diffidence; and that, I dare not preſume to expect they will produce any permanent conviction in others, becauſe I experience an inſtability of opinion in myſelf. For to uſe the language of Tully, *Neſcio quomodo, dum lego aſſentior; cùm poſui librum, aſſenſio omnis illa elabitur.*—But this ſcepticiſm is perhaps to be aſcribed to the influence of habitual preconceptions, rather than to a deficiency of reaſonable proof. For beſides the various arguments which have been advanced, in favour of vegetable perceptivity, it may be further urged, that the hypotheſis recommends itſelf, by its conſonance to thoſe higher analogies of nature, which lead us to conclude, that the greateſt poſſible ſum of happineſs exiſts in the univerſe. The bottom of the ocean is overſpread with plants, of the moſt luxuriant magnitude. Immenſe regions of the earth are covered with perennial foreſts. Nor are the Alpes, or the Andes, deſtitute of herbage, though

though buried in depths of ſnow. And can it be imagined, that ſuch profuſion of life ſubſiſts without the leaſt ſenſation or enjoyment? Let us rather, with humble reverence, ſuppoſe, that vegetables participate, in ſome low degree, of the common allotment of vitality: And that our great Creator hath apportioned good, to all living things, in number, weight, and meaſure."*

SUPPLEMENT *to the foregoing* PAPER; *containing further Obſervations on the* SENSITIVE PLANT.

IN the ſpeculations, concerning the perceptive power of vegetables, which were read before this Society laſt ſpring, I obſerved, that the motions of the ſenſitive plant are not to be explained by the laws of electricity. For its leaves are alike affected by the contact of electric and non-electric bodies; ſhew the ſame ſenſibility whe-

* It has been eſtimated, that our globe contains 20,000 ſpecies of vegetables; 3000 of worms; 12,000 of inſects; 200 of amphibious animals; 2600 of fiſhes; 550 of birds; and 200 of quadrupedes. (Vid. Linn. Amænit. Academ. and Stillingfleet's Miſcellaneous Tracts, p. 125). A calculation like this, it is evident, muſt be very defective; becauſe founded on paſt diſcoveries in a ſcience, which is now in a ſtate of rapid progreſſion. But future acceſſions, both of plants and animals, with reſpect to number, may produce no material changes in their relative proportions.

ther

ther the atmoſphere be dry or moiſt; and inſtantly cloſe when certain chemical ſtimuli, ſuch as the vapour of vol. alkali, or the fumes of burning ſulphur, are applied to them. Theſe concluſions were founded on the recollection of experiments which I made more than twenty years ago. But the Abbè Barthalon de St. Lazane, in a late treatiſe on the electricity of vegetables, has adopted an oppoſite hypotheſis, and adduced the following trials in ſupport of it. When the ſenſitive plant, ſays he, is touched with a piece of poliſhed metal, terminated at each end by a round knob, its leaves ſhrink back and ſhut. When it is touched with a piece of glaſs, of the ſame form, it remains inſenſible. But if this piece of glaſs be electrified, and the plant be touched with it in this ſtate, the leaves inſtantly cloſe themſelves. Hence he infers, that the plants called Mimoſæ are endued with a much greater portion of electrical fluid than others; that this fluid eſcapes when touched by a foreign body, capable of conveying it away; and that they ſhrink by being thus deprived of what is eſſential to their health and vigour.*

I have lately procured a ſenſitive plant, with the deſign of repeating the Abbè's experiments.

* See Abbè Barthalon de St. Lazane D'Electricité des Vegeteaux: Alſo Appendix to Monthly Review, vol. XVII. p. 135.

But

But at the prefent feafon of the year, I find this vegetable in a very languid ftate; fo that my trials have not afforded me much fatisfaction. I could not, however, perceive any difference, whether the leaves were touched with a piece of polifhed iron, or a ftick of fealing wax. And the following well authenticated facts, feem to refute the Abbé's hypothefis, concerning the electrical œconomy of this plant.

I. The branches of the fenfitive plant have two motions, the one natural, the other artificial. By the firft it progreffively increafes, in the morning, the angle which it forms with the ftem; and retreats in the fame gradual manner, in the afternoon. By the fecond it contracts its leaves, when forcibly touched or fhaken.

II. The fenfibility of the plant feems, chiefly, to refide in the articulation of the branches of the common foot ftalk, or of the particular foot ftalk of each wing.

III. No motion enfues from cautioufly piercing the branch with a needle, or other fharp inftrument.

IV. A ftroke, or an irritation, produces a more forcible effect, than an incifion or even an entire fection.

V. A flight irritation only acts upon the neighbouring parts, and extends its influence according to its force.

 VI. Plun-

VI. Plunging the plant in water ſeems to have no other effect, than that of diminiſhing its vigour.

VII. A piece of wax, ſtrongly electrified, made the leaves of the ſenſitive plant cloſe quickly, by attracting them to it with conſiderable force.

VIII. The motions of the ſenſitive plant are owing to a ſtrong contraction. Each foot ſtalk ſeems to be terminated with a kind of joint, on which the leaves turn, with ſurprizing facility.*

NOVEMBER 9, 1784.

* Conſult Milnes's Botanical Dictonary; the Encyclopædia Britannica; and Whytt on Vital Motions.

An EXPERIMENTAL INQUIRY *into the* CAUSE *of the* PERMANENT COLOURS *of* OPAKE BODIES. *By* EDWARD HUSSEY DELAVAL, F. R. S. *of the* ROYAL SOCIETIES *of* UPSAL, *and* GOTTINGEN, *of the* INSTITUTE *of* BOLOGNA, *and of the* LITERARY *and* PHILOSOPHICAL SOCIETY *of* MANCHESTER. *Communicated by Mr. Charles Taylor. Read May* 19, 1784.

THE chief deſign of this inquiry is, to inveſtigate the nature, origin, and cauſe, of the permanent colours of opake bodies.

I was led to the purſuit of it, from a perſuaſion of its utility, to thoſe intereſting and elegant Arts, whoſe object is the preparation, and uſe, of colouring ſubſtances.

The diſcovery of this principle is the foundation, on which alone all the parts and materials of the knowledge, relative to thoſe Arts, can be raiſed and ſupported.

It ſhould be the office of experimental philoſophy, to examine the powers and properties of all the materials, requiſite to technical uſes. Nor ſhould its views be confined to the theories, which reſult from thoſe reſearches, but directed to the practical application of them.

In proportion as the Principles of any Science are unknown or misconceived, the advancement of the Arts and Manufactures, which depend on them, must of course be impeded: for, without those guides, no addition or improvement can be attained, except such as arise from mere accidental observation.

But when scientific Principles are disclosed to the Artist, he becomes enabled to draw, from those original sources, an ample store of useful inventions, by which his Art is constantly enriched; and from thence considerable advantages may be derived. And thus the speculative Sciences, by their extension to practical purposes, become objects of great public utility.

The truth of this observation is, in no instance, more conspicuous, than when applied to the Science of Optics, and to the Arts and Manufactures, which are connected with, and dependent upon it. For, the invention and improvement of the several operations, which owe their rise to that Science, appear to have kept an equal pace with the philosophical discoveries, by which they were suggested: and their progress seems to have been constantly retarded, in proportion as the correspondent branches of the parent Science have remained in a state of deficiency or imperfection.

The experiments and observations, which have been made by means of Transparent Colourless

Substances,

Subſtances, are very numerous, and the action and powers of ſuch bodies, in reflecting and refracting light, have been, in a great meaſure, diſcovered and explained.

In conſequence of thoſe diſcoveries, optical inſtruments have been brought to a conſiderable degree of perfection.

It is further obſervable, that from the miſconception of a ſingle circumſtance, in this department of the ſcience, there aroſe an obſtacle to the conſtruction of teleſcopes, which the united efforts of artificers were unable to ſurmount, till the error was rectified.

This error, which had eſcaped even the penetration of Sir Iſaac Newton, originated from a ſuppoſition, that the divergency of all the rays, which paſs through any media, is conſtantly equal to their refraction.

The inaccuracy of this opinion was firſt obſerved by M. Euler, and the ſubject was afterwards attentively purſued by the Academicians Clairaut, Klingenſtierna, Beguelin, Zeiher, and D'Alembert: but, we are indebted to M. Dolland, for the final diſcovery of the Principles, and their application to the conſtruction of teleſcopes, ſuperior to any which had ever been before produced.

In this happy inſtance, the genius of the Philoſopher, and the hand of the Artiſt, were united in the ſame perſon.

I have thus briefly confidered the prefent ftate of our knowledge, of the optical properties of Colourlefs Tranfparent Subftances; and the condition and progrefs of the Arts which are fubordinate to, and connected with them.

The induftry and attention of philofophers has not hitherto, in any great degree, been excercifed on the confideration of Permanently Coloured Bodies.

It will appear, in the courfe of this inquiry, that the difpofition of fuch fubftances to exhibit their colours, has not been examined by experiments, which are the true and only means of difcovering, and explaining, its caufe. And it will be fhewn, that the hypothetical opinions, which have been offered on this fubject, are not fupported by actual obfervations, and do not account for, or agree with, the phænomena.

From the imperfection of this branch of Optics, and from the influence which its defects exert on thofe Arts, whofe improvement depends upon a clear and juft conception of the nature, preparation, and ufe of colouring materials, it is not difficult to deduce the reafon of the immaturity, and deficiency, under which they labour.

So far, indeed, are we from having advanced towards a ftate of perfection, that if we caft our views back to the remoteft regions of Science, we fhall find, from fuch a retrofpect, that the moft

moſt ancient nations poſſeſſed an excellence in all thoſe Arts, which the ableſt moderns cannot diſpute with them.

In a former work, I have ſhewn that the Art of Dying was cultivated in the remoteſt ages, in Phœnicia, Egypt, India, the land of Canaan, and other countries; and that they excelled even in the moſt difficult and elaborate branches of this art. They were alſo ſkilled in making artificial gems, and tinging glaſs, and enamel, with the brighteſt colours.

From the teſtimony of the earlieſt hiſtorians, we are informed of the high antiquity of the Art of Painting, in Egypt, and other countries which gave birth to the Arts and Sciences: and many beautiful remains of antiquity, which are ſtill extant, are clear and laſting proofs of the great proficiency of thoſe ancient nations in that Art.

Theophraſtus, Pliny, and others, have enumerated the colours, employed in the various methods of antique painting.

Theſe colours include almoſt all the pigments, which are employed by the moderns. Pruſſian Blue, which, with a few others, has been added, was diſcovered by an accidental mixture of the ingredients, which enter into the compoſition of it. Nor is it ſo durable as the blue paints, which were in uſe before its introduction.

Pliny informs us, that in his time Painting had greatly degenerated from its former ſtate.

It is not my purpose in this brief review of the colouring arts, to advert to their condition at that period, as they had then fallen from their primitive excellence; nor to consider them in any other respect, than that which regards the beauty, and durability, of the colours, abstracted from any other circumstances whatsoever.

The paints, which Apelles used, were so bright, that he found it expedient to glaze his pictures, with a dusky varnish, that the vividness of the colours might not offend the sight.*

But notwithstanding the allowed merit of this celebrated painter, and of his cotemporaries, in the execution of their art, their colours were greatly surpassed, in variety, brightness, and permanency, in the works which had been perfected long before such arts were cultivated in Greece; and which, after so long a series of ages, still continue unimpaired, and probably will ever remain so, unless destroyed by violence.

I have selected the following passages, relative to this subject, from the authentic description

* Inventa ejus et cæteris profuere in arte. Unum imitari nemo potuit, quod absoluta opera atramento illinebat ita tenui, ut idipsum repercussu claritates oculorum excitaret, custodiretque a pulvere et sordibus, ad manum intuenti demum appareret. Sed et tum ratione magna *ne colorum claritas oculorum aciem offenderet*, veluti per lapidem specularem intuentibus è longinquo.

Plinii L. XXXV. Cap. 10.

which

which Norden has given of the extenſive and magnificent remains of Thebes, in the Upper Egypt, which was the capital of the Eaſtern World. That traveller, in a letter to the Baron de Stoſch, thus relates his obſervations.

" I hope to get the author you tell me of, but " as he treats only of the paintings upon the caſes " of the Mummies, he will be of no great uſe to " me in explaining thoſe wonderful ones, that " I have ſeen upon an infinite number of ancient " buildings, or in giving the leaſt idea of them. " Imagine to yourſelf, in the extent of an Italian " league, palaces with columns thirty-two French " feet in circumference, caſed with ſandy ſtones " cut in ſquares, and all over covered, within " and without, with paintings, repreſenting the " worſhip of the deities of the country, the " ceremonies and cuſtoms of the inhabitants, " their manner of making war and ſailing, " together with love devices intermixed. Con- " ſider likewiſe, that the manner of painting is " ſo totally different from any thing in practice " at this time, as to make it neceſſary for me " to give you ſome ſlight idea of it. A painting " eighty feet high, and proportionably broad, " is divided into two ranges of gigantic figures " in baſs relief, and covered with moſt exquiſite " colours, ſuited to the drapery and naked parts " of the figure. But what is ſtill more wonder- " ful is this, that the *azure, the yellow, the green,*

" *and*

" *and the other colours made uſe of, are as well* " *preſerved, as if they had been laid on but yeſterday,* " *and ſo ſtrongly fixed to the ſtone, that I was never* " *able to ſeparate them in the leaſt degree.* You " will aſk me, whether the deſign is good and " has taſte? yes, Sir, the whole is executed " with much greater exactneſs, than the idols " of granite which we both have ſeen in the " Capitol."*

Theſe further remarks are cited from the journal of the ſame author.† " We paſſed " afterwards

* Norden's Travels in Egypt, by Templeman, p. 33.

† Ib. vol. II. p. 75.

In confirmation, and as a farther explanation of theſe accounts, I ſhall here inſert ſome extracts from Perry's voyage to Upper Egypt, which abounds in deſcriptions and praiſes of the paintings, that adorn the temples and palaces of that ſplendid ſcene of antiquity.

‖ " At Carnac (commonly called Luxor il Kadim, and " formerly a part of Thebes) we went aſhore, and marching " along, with great avidity directly to it, we found the " moſt ſtately, magnificent and ſurprizing temple that ever " eye beheld: doubtleſs, it is impoſſible to think, ſpeak, or " write of this edifice, without tranſport or rapture; for its " ſplendour, glory, and magnificence are ſuch, as are truly " unſpeakable, and perhaps inconceivable. The front of this " portal from top to bottom, on each ſide for a width of nine " or ten feet, and the whole inner ſide of the portal the ſame, " are all filled with the moſt beautiful figures in baſſo relievo, " and

‖ A View of the Levant, by C. Perry, M. D. London. 1743. p 341.

" afterwards to the ruins, that are found on the " north ſide. There is no doubt but they are " the remains of the palace of Memnon.

" The reader may there remark, letter C the " portico of a temple, capable of giving a great " idea of the Egyptian architecture.

" The hieroglyphics are agreeable to the " ſight, and when you are quite near, *their co-* " *lours have a charming effect.*

" It is ſomething ſurpriſing to ſee how *gold,* " *ultra marine, and divers other colours, have pre-* " *ſerved their luſtre to the preſent age.*"

" and hieroglyphics, and all theſe are *painted over in a moſt* " *curious and exquiſite manner.*

" This grand ſumptuous portal, is no other than a paſ- " ſage which leads from the firſt court or ſalon, into a ſe- " cond. This ſalon, which is equimenſurate with the for- " mer, viz. one hundred paces wide, and ſixty deep, is per- " fectly crowded with pillars, like the former as to ſhape and " ornaments, only that theſe are larger, being near twelve " feet in diameter, and ſeventy-two feet high: all theſe co- " lumns as well as the ceiling, roof and walls of the apart- " ment are quite covered or crowded with figures in baſſo " relievo, and hieroglyphics, *all exquiſitely beautiful, and* " *finely painted all over*—and which may ſeem very extraor- " dinary, all theſe things *look as freſh, ſplendid and glorious,* " *after ſo many ages, as if they were but juſt finiſhed.*"

Diodorus Siculus, in his deſcription of Thebes, mentions ſuch gigantic figures, covered with the moſt beautiful co- lours, as well as the other kinds of paintings, which are ſtill extant in the remains of that city.

Such

Such was the ſtate of Painting in Egypt, above three thouſand years ago. The other colouring arts were carried to a high degree of improvement, at an equally remote period.

We learn, from the concurrent teſtimony of both ſacred and profane hiſtorians, that the countries, where theſe Arts originally flouriſhed were antecedent, and ſuperior to all others, in their diligent and ſucceſsful obſervations of nature, and in the invention and culture of the Sciences.

Theſe, undoubtedly, gave riſe to the executive Arts, and opened a way to their advancement and perfection.

But, after a ſucceſſion of ſeveral ages, both the theoretical knowledge, and the practical ſkill, of thoſe nations, underwent a conſiderable decline, and ſhared the general deſolation which had befallen, from civil diſaſters, and foreign invaſions.

Thoſe repoſitories of the Arts and Sciences had already far receded from their primeval condition, at the time that the ancient ſages of Greece reſorted to them, for inſtruction.

So that, although the reſearches of thoſe travellers were repaid by the acquirement of ſome general phyſical truths, which had been traditionally preſerved, they could not, by the moſt diligent inquiry, attain an inſight into any of the progreſſive means of information, from which ſuch truths had been deduced.

Nor

Nor were they enabled, on their return to their own country, to transfer to it the methods of executing thofe beautiful and magnificent works, which had been the objects of their admiration.

The moderns were not furnifhed with any adequate means of retrieving the Principles of ancient Science, till they began to avail themfelves of experimental obfervations; and till academies were inftituted, for the purpofe of enabling them mutually to communicate their difcoveries to each other.

The prefent age has produced many excellent philofophers, whofe labours have been directed to inquiries, from whence great improvements muft neceffarily refult to the Arts, and Operations, which are of the higheft importance to the convenience and happinefs of mankind.

I fhall think myfelf fortunate, if the flight addition of my endeavours prove, in the leaft degree, conducive to that end.

In a former work, I have confidered the Differences or Changes of Colour, in permanently coloured bodies, and have fhewn that they are effected in the fame manner, and according to the fame law, which prevails in Tranfparent Colourlefs Subftances.

By this means, the philofophical principle is eftablifhed, and applied to the practical ufes of feveral Arts: particularly to thofe of Dying, Painting,

ing, and fuch others as depend upon the know-ledge, and management, of Colouring Materials.

The experiments, by which the caufe of thofe changes of colours was inveftigated, confifted chiefly of various methods of uniting the Colouring Particles into larger, or dividing them into fmaller, maffes.

I fhall now proceed to examine thofe properties of Permanently Coloured Subftances, by which they operate on the rays of light, in producing colours.

No effential information, relative to this fubject, can be obtained from any optical writers, who preceded Sir Ifaac Newton. For, the origin and nature of light and colours were entirely unknown, till they were unfolded by his refearches.

To him we owe the difcovery of the different refrangibility of the rays of light; the invariable colours of the differently refrangible rays; the power of thin tranfparent plates, particles, and fibres, to exhibit feveral colours, according to their feveral thickneffes and denfities; as well as the inveftigation and explanation of feveral other properties of light.

All thefe were refults of experiments made by means of Tranfparent Colourlefs Media. But, he does not appear to have examined, with equal attention and fuccefs, the properties of Permanently Coloured Bodies, and their operations on the

the rays of light. And indeed, from the ſtate and extent of his reſearches, it was not poſſible that he could have attained to a clear inſight into that part of Optics, as he was not furniſhed with any regular ſeries of experiments, which could be applied to the ſolution of its phænomena.

As the progreſs of Sir Iſaac Newton's diſcoveries did not extend beyond the limits of his experiments, it may be fairly concluded, that, without ſuch ſources of information, the moſt acute and penetrative underſtandings muſt fail of ſucceſs in phyſical inquiries.

This great philoſopher, however, in the few paſſages wherein he treats of Coloured Subſtances, conſtantly avows his defect of experiments. It is probable that, by this candid acknowledgment, he intended that the opinions which he had expreſſed, on this ſubject, which are merely conjectural or founded on abſtract ſpeculation, might be diſtinguiſhed from thoſe clear truths, which he had deduced from his numerous and accurate experiments, performed with Tranſparent Colourleſs Bodies.

Thus, having mentioned ſome of thoſe ſubſtances, which tranſmit one ſort of light and reflect another ſort, he makes this remark: "If "theſe liquors or glaſſes were ſo thick and maſſy, "that no light could get through them, I queſ- "tion not but they would, like all other opake "bodies,

"bodies, appear of one and the fame colour, "in all pofitions of the eye, though this I cannot "yet affirm by experience." *

And he thus expreffes himfelf, relative to the opacity of glafs wedges filled with red, and blue liquors, when viewed conjointly. "This Mr. "Hook tried cafually with glafs wedges filled "with red and blue liquors, and was furprized "at the unexpected event, the reafon of it being "then unknown; which makes me truft the "more to his experiment, though I have not "tried it myfelf." †

We find, at the clofe of the Optics, a paffage relative to the inflections of the rays of light and the colours made thereby, which feems capable of being extended to all thofe obfervations, which the illuftrious author had left imperfect, or had not profecuted with that eminent degree of induftry and circumfpection, which are generally confpicuous in his inquiries. It is as follows: "When I made the foregoing obfer-"vations, I defigned to repeat moft of them "with more care and exactnefs; but I was then "interrupted, and cannot now think of taking "thefe into farther confideration." ‡

Sir Ifaac Newton was of opinion, that *all Coloured Matter reflects* the rays of light, fome

* Newton. Opt. L. I. Part. II. Prop. X. Probl. V.

† Ib. ‡ Ib. L. III. ad calc.

bodies

bodies *reflecting* the more refrangible, others the lefs refrangible rays, more copioufly. And that "this is not only a true reafon of thefe colours, but even the only reafon."*

He conceived that opake bodies reflect the coloured light from their anterior furface, by fome power of the body evenly diffufed all over its furface, and external to it.

He thus delivers his doctrine relative to tranfparent coloured liquors.† "A tranfparent body "which looks of any colour by tranfmitted light, "may alfo look of the fame colour by reflected "light, the light of that colour being reflected "by the farther furface of the body, or by the "air beyond it. And then the reflected colour "will be diminifhed, and perhaps ceafe, by "making the body very thick, and pitching it "on the back fide to diminifh the reflection of "its farther furface, fo that the light reflected "from the tinging particles may predominate. "In fuch cafes, the colour of the reflected light "will be apt to vary from that of the light "tranfmitted."

As thefe opinions are merely hypothetical, and are not fupported by the evidence of any experiments, I judged it expedient carefully to inquire into the phænomena of Coloured Subftances,

* Ib. L. I. Par. II. Prop. X. Probl. V.

† Ib.

 from

from which alone any clear illuſtration of ſuch queſtions can be attained.

For this purpoſe, I entered upon a ſeries of experiments, which have been performed with Tranſparent Coloured Liquors, and Glaſſes, as well as with opake, and ſemitranſparent bodies.

I ſhall, in the firſt place, conſider Tranſparent Coloured Subſtances; becauſe they are of the ſimpleſt kind, as they conſiſt only of the Colouring Particles united with, and diffuſed throughout, Tranſparent Media, ſuch as ſpirit of wine, oil, water, or glaſs.

From the examination of ſuch tinged media, I have been enabled to diſcover ſeveral properties of Coloured Matter, which are very different from thoſe, which have hitherto been thought to prevail.

For inſtance, it will appear from the experiments which I ſhall relate in the ſequel, that in Tranſparent Coloured Subſtances, the Colouring Matter *does not reflect any light*; and when by intercepting the light which was tranſmitted, it is hindered from paſſing through ſuch ſubſtances, they do not vary from their former colour,* to any other colour, but become entirely *black*.

As

* Optical writers generally uſe the word *colour* in an equivocal ſenſe: ſometimes expreſſing thereby the primary colours, as oppoſed to whiteneſs: at other times including whiteneſs alſo. I have, throughout this inquiry, uſed this word

As the incapacity of the Colouring Particles of Tranſparent Bodies to reflect light, is deduced from experiments which are very numerous, and whoſe reſults are conſtant and invariable, it may be held as a general law, at leaſt till ſome exception to it can be diſcovered.

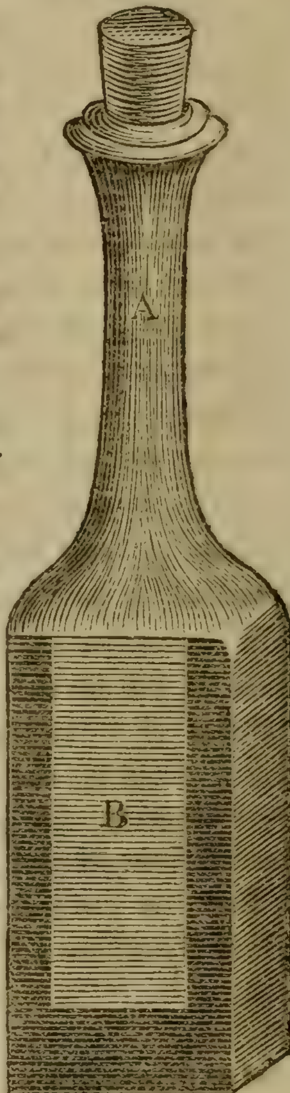
This law will appear ſtill more extenſive, if it be conſidered that, for the moſt part, the tinging Particles of liquors, or other Tranſparent Subſtances, are extracted from Opake Bodies; that the Opake Bodies owe their colours to thoſe particles in like manner as the Tranſparent Subſtances do, and that by the loſs of them, they are deprived of their colours.

By experiments made with ſeveral Opake Bodies, it will be ſhewn that they actually do not exhibit their colours, by reflecting the rays of light. And, by the ſame experiments, the means, by which they do produce their colours, will be hereafter explained.

For the purpoſe of obſerving the manner in which Tranſparent Coloured Liquors act upon the

word to expreſs only the *primary colours*, or ſuch a mixture of them, as does not compoſe whiteneſs, or any of the gradations between white and black; ſuch as are called by Sir Iſaac Newton, grey, dun, or ruſſet brown.

rays of light, I procured fmall vials of flint glafs, whofe form is a parallelepipid; the height of thefe, exclufive of the neck, is about two inches, and the bafe about one inch fquare; their necks are cylindrical, and are about two inches in length.



I covered the bottom, and three of the fides of each of thefe vials, with a black varnifh; the cylindrical neck, A, and the anterior fide, B, except at its edges, were left uncovered.

I carefully avoided leaving any crevices in the varnifh, that no light might be admitted, except through the neck, or the anterior fide, of the vials.

In thefe experiments, both the inner and exterior furfaces of the glafs muft be perfectly clean; and thofe liquors, which are apt to depofit a fediment on the bottom or fides of the veffels which contain them, muft be put into the vials, only when the examination of them is intended: thofe, which are not fubject to

to this inconvenience, may be conſtantly kept in the vials.

The uncovered ſide of the vial ſhould not be placed oppoſite to the window, through which the light is admitted; becauſe in that ſituation the light would be reflected from the farther ſide of the vial, and would be tranſmitted through the coloured liquor; and it is obſervable that ſmooth black ſurfaces reflect light very powerfully. Now as it is a principal object in the experiment that no light be tranſmitted through the liquors, this will be accompliſhed by placing the uncovered ſide of the vial in ſuch a direction, that it may form a right angle with the window.

I have examined a great variety of Tranſparent Coloured Liquors, in vials, prepared and diſpoſed as I have here deſcribed, and have conſtantly found that in every inſtance, that part of the liquor, which was contained in the neck of the vials, exhibited its colour diſtinctly and vividly; but, that portion, which was in the body of the vials, and which was viewed through the uncovered ſide, *exhibited no colour*, but was *black.*

From amongſt numerous ſimilar obſervations, I have ſelected thoſe which are ſet down in the following table: I have not attempted therein to produce any regular or ſyſtematical collection of coloured liquors, but only to exhibit ſuch ſpecimens as may ſerve to ſhew the action of

vegetable, mineral, and animal colouring particles, on the rays of light.

The expreſſions, *reflected light*, and *tranſmitted light*, have been generally uſed, when Tranſparent Coloured Bodies have been conſidered. But, as the following experiments and obſervations, ſhew that Tranſparent Coloured Bodies are not endued with any *reflective* power, the word *reflected*, cannot properly be applied to the light which falls on them. I have, therefore, at the head of the laſt column of this table, ſubſtituted the words "*incident light*," inſtead of the uſual expreſſion, *reflected light*.

TABLE *of* TRANSPARENT COLOURED LIQUORS *viewed by* TRANSMITTED, *and by* INCIDENT LIGHT.

LIQUORS.	By Tranſmitted Light.	By Incident Light.
1. Iron diſſolved in the Nitrous Acid	Yellow	Black
2. Martial Alcaline Tincture of Stahl	Orange	Black
3. Vitriol of Iron diſſolved in Water	Green	Black
4. Dilute Solution of Green Vitriol, with Infuſion of Galls - - -	Blue	Black
5. Dilute Solution of Green Vitriol in Spirit of Wine, with Tincture of Galls in Spirit of Wine - - -	Blue	Black
6. Saturated Solution of Fixed Alcali, in which a ſmall Quantity of Green Vitriol is diſſolved, with Infuſion of Galls - - - - -	Red	Black

7. Dilute

LIQUORS.	By Transmitted Light.	By Incident Light.
7. Dilute Solution of Green Vitriol, with Phlogisticated Alcaline Lixivium	Blue	Black
8. Spa, and Pyrmont, Waters, with Infusion of Galls - - - -	Purple	Black
9. Solution of Vitriol of Copper -	Blue	Black
10. Copper dissolved in Nitrous Acid	Blue	Black
11. Crystals of Verdegris, dissolved in Distilled Vinegar - - -	Blue *Green*[*]	Black
12. Copper dissolved in Volatile Alcali	Blue	Black
13. Manganese fused with Nitre, or with Fixed Alcali, dissolved in cold Water	Green	Black
14. Manganese, thus prepared, dissolved in hot Water - - -	Purple	Black
15. Cobalt dissolved in Nitrous Acid	Red	Black
16. Marine Acid, to which a small quantity of Nitrous Solution of Cobalt is added - - - -	Green	Black
17. Sympathetic Ink of Cobalt -	Red	Black
18. Solution of Gold - - -	Yellow	Black
19. Dilute Solution of Gold, with Solution of Tin - - - -	Red	Black
20. Solution of Platina - - -	Orange	Black

[*] The names of the colours, which are printed in Italic characters, express those to which the principal colours, contained in the table, incline.

21. Red

LIQUORS.	By Tranfmitted Light.	By Incident Light.
21. Red Flowers, infufed in Spirit of Wine, flightly acidulated with Nitrous Acid - - -	Red	Black
22. Red Flowers infufed in Water, flightly acidulated with Nitrous Acid	Red	Black
23. Purple, and Blue Flowers, infufed in Water, flightly acidulated with Nitrous Acid - - -	Red	Black
24. Purple, and Blue Flowers, infufed in Spirit of Wine, flightly acidulated with Nitrous Acid - -	Red	Black
25. The fame Red Infufions, with the addition of fmall quantities of Solution of Fixed Alcali - -	Purple Blue Green	Black
26. Yellow Flowers infufed in Diftilled Water - - -	Yellow	Black
27. Yellow Flowers infufed in Spirit of Wine - - -	Yellow	Black
28. Green Colouring Matter of Grafs, and other Green Leaves, diffolved in Spirit of Wine - -	Green Yellow Red	Black
29. Prepared Turnfol infufed in Water	Purple	Black
30. Juice of Black Currants - -	Red	Black
31. Black Cherries, Black Currants, and other Black Fruits and Berries, infufed in Spirit of Wine -	Red	Black
32. Rafpberries, and other Red Berries, infufed in Spirit of Wine -	Red	Black

LIQUORS.	By Tranfmitted Light.	By Incident Light.
33. Spanifh Annotto diffolved in Spirit of Wine - - - - -	Yellow	Black
34. Spanifh Annotto diffolved in Cauftic Vegetable Fixed Alcali - -	Yellow	Black
35. French Berries infufed in Spirit of Wine - - - - -	Yellow	Black
36. French Berries infufed in Diftilled Water - - - - -	Yellow	Black
37. Sap Green infufed in Spirit of Wine	Green	Black
38. Sap Green infufed in Diftilled Water	Green Yellow Red	Black
39. Indigo diffolved in Oil of Vitriol, and afterward diluted with Water	Blue	Black
40. Indigo diffolved in Cauftic Vegetable Fixed Alcali - - - -	Green	Black
41. Litmas infufed in Diftilled Water	Red Purple Blue	Black
42. Prepared Archil, Water - -	Purple	Black
43. Prepared Archil, Spirit of Wine	Purple	Black
44. Gamboge diffolved in Spirit of Wine	Yellow	Black
45. Dragon's Blood diffolved in Spirit of Wine - - - - -	Orange	Black
46. Weld infufed in Diftilled Water	Yellow	Black
47. Madder infufed in Spirit of Wine	Orange	Black
48. Alaknet infufed in Spirit of Wine	Red	Black
49. Alkanet infufed in Oil of Turpentine	Red	Black

50. Alkanet

LIQUORS.	By Transmitted Light.	By Incident Light.
50. Alkanet infused in Expressed Oils	Red	Black
51. Fustic infused in Distilled Water	Yellow	Black
52. Fustic infused in Spirit of Wine	Yellow	Black
53. Turmeric infused in Spirit of Wine	Yellow	Black
54. Turmeric infused in Distilled Water	Yellow	Black
55. Logwood infused in Distilled Water	Yellow	Black
56. Logwood infused in Thames Water	Red	Black
57. Logwood infused in Spirit of Wine	Yellow	Black
58. Red Saunders infused in Spirit of Wine	Red *Orange*	Black
59. Cochineal infused in Distilled Water	Red	Black
60. Cochineal infused in Spirit of Wine	Red	Black
61. Kermes infused in Distilled Water	Yellow	Black
62. Kermes infused in Spirit of Wine	Yellow	Black
63. Ox Gall, diluted with Distilled Water	Yellow	Black
64. Blood with Spirit of Sal Ammoniac	Red	Black
65. Spirit of Nitre impregnated with Phlogiston - - - - -	Yellow	Black
66. The same with Distilled Water	Green	Black
67. Nitrous Spirit distilled from equal parts of Arsenic and Nitre -	Green	Black
68. The same with Distilled Water	Blue	Black

These

These experiments ſhew, that Tranſparent Coloured Liquors do not yield any colour by reflection, but by tranſmiſſion only.

If theſe liquors are ſpread thin on any white ground, they appear of the ſame colours, which they had exhibited, when viewed in the necks of the vials; as the light reflected from the white ground is, in this caſe, tranſmitted through the coloured medium.

But when they are ſpread upon a black ground, they afford no colour. The black ground, however, ſhould not be a poliſhed body; as the light, reflected thereby, would be tranſmitted through the thin medium on its ſurface, and be tinged by paſſing through it.

I ſhall now proceed to relate ſome experiments, which were performed with tinged glaſſes: theſe being, in many reſpects, analogous to coloured liquors.

I made ſeveral parcels of colourleſs glaſs. That, which I principally employed in theſe experiments, conſiſted of equal parts of borax and white ſand. The glaſs was reduced to powder, and afterwards ground, together with the ingredients by which the colours were imparted.

This method, of incorporating the tinging particles, is greatly preferable to mixing them with the raw materials. The glaſſes, thus compoſed, excel moſt others in hardneſs, and are ſcarcely inferior, in luſtre, to real gems.

All

All the experiments, which have been made with *tranſparent coloured glaſſes*, ſhew that they appear vividly coloured, when they are of ſuch a thinneſs, and are tinged ſo dilutely, that light is tranſmitted through them. But when they are in larger maſſes, and the tinging matter is more denſely diffuſed through them, they are *black*. For, theſe as well as the *tranſparent coloured liquors do not exhibit colours by reflection*, but by *tranſmiſſion* only.

I ſhall here inſtance ſome trials, which I made for the purpoſe of obſerving the proportions of tinging matter, which produce colour, or blackneſs.

I tinged glaſs green, by adding to it one ſixtieth part of its weight of copper. It is indifferent whether the copper, uſed in this proceſs, be calcined, or applied in its metallic ſtate.

I made a blue glaſs, by the addition of zaffre, a purple glaſs by manganeſe, a red glaſs by gold, and yellow glaſſes by ſilver, and by calcined iron. I alſo made a yellow glaſs, ſimilar to a topaz, by the admixture of a ſmall quantity of pulverized charcoal: and the ſame colour was imparted by wheat flower, by roſin, and by ſeveral other inflammable matters.

From the maſſes of tranſparent coloured glaſs, which were thus compoſed, ſmall pieces were ſeparated, and ground by a lapidary, which reſembled gems of their reſpective colours.

Having

Having formed pieces of ſuch glaſſes, about two inches thick, I incloſed all their ſides with black cloth, except at their farther, and anterior ſurfaces. Each of theſe pieces of glaſs vividly exhibited its colour, when viewed by tranſmitted light: but when the tranſmitted light was intercepted, by covering the farther ſurface, the anterior ſurface afforded no colour, but appeared *black.*

When plates of Tranſparent Coloured Glaſs, ſomewhat thicker than window glaſs, are viewed by tranſmitted light, it is well known, that they exhibit their ſeveral colours.

I intercepted the light, which was tranſmitted through ſuch coloured plates, by fixing a piece of black cloth, contiguous to their farther ſurface. The plates, thus prepared, when placed in ſuch a direction, that they form a right angle with the window, appear perfectly *black.*

From the phænomena, preſented by ſuch plates, two obſervations may be deduced. (1.) That the Colouring Particles do not reflect any light. (2.) That a medium, ſuch as Sir Iſaac Newton has deſcribed, is diffuſed over both the anterior, and farther ſurfaces of the plates, whereby objects are reflected equally, and regularly, as by a mirror.*

* Whenever it is ſaid that light is reflected by the ſurface of any ſubſtance, it ſhould be underſtood, from this expreſſion, that the reflection is effected by the medium, diffuſed over its ſurface.

When

When a lighted candle is placed near one of these coloured plates, the flame is reflected by the medium, which is diffused over the anterior surface of the plate. The image, thus reflected, resembles the flame, in size, and colour. For, it is scarce sensibly diminished, and *it is not in the least tinged by the coloured glass.*

If the plate be not so intensely coloured, or so massy, as to hinder the transmission of the light of the candle, there appears a secondary image of the flame, which is reflected by the medium, contiguous to the farther surface of the glass. And as the light, thus reflected, passes back through the coloured glass, it is vividly tinged by it.

When the glass, used in this experiment is green, the secondary image of the flame assumes a bright green colour. When glasses of other colours are used, the colour of the secondary image is always the same, as that of the glass.

The secondary image is less, than that which is reflected from the anterior surface. This diminution is occasioned by the loss of that part of the light, which is absorbed, in passing through the coloured glass. For, whenever any medium transmits one sort of rays, more copiously than the rest, it stops a great part of the oppositely coloured rays. And much more light is lost, in its passage through coloured, than through pellucid colourless, substances.

In

In making theſe obſervations, it is proper to choofe coloured plates of glaſs, which are not in every part of an equal thickneſs, that the ſecondary image may not be reflected in ſuch a direction, as to coincide with, and be intercepted by, that which is reflected from the anterior ſurface.

When the plates are ſo thick, and ſo copiouſly coloured, that the light cannot penetrate to their farther ſurface, they appear intenſely *black*, in whatever direction they are viewed, and they do not afford any ſecondary image; but only reflect from their anterior ſurface, the flame, or any other objects which are oppoſed to them. Theſe objects are repreſented in their own proper colours, and are as free from any tinge, or adventitious colour, as thoſe which are reflected from looking glaſſes, or ſpecula made of white metals.

It is manifeſt from hence, that the colouring particles have no ſhare in effecting this reflection. For, if they poſſeſſed any reflective power, whence is it that glaſſes, copiouſly ſtored with colouring matter, impart no colours to the images, which they reflect?

It appears, from theſe obſervations, that tranſparent coloured bodies, as well in a ſolid, as in a fluid, ſtate, exhibit colours by tranſmiſſion only, but do not reflect any colour.

The order of this inquiry leads me, in the next place, to the conſideration of the Colouring Particles, *pure, and unmixed with other media.*

For

For the purpose of procuring masses made up of such particles, I reduced several Transparent Coloured Liquors to a solid consistence, by evaporation. When a gentle heat is employed in this operation, the Colouring Matter, which is thus concentrated, remains unimpaired, and capable of again imparting its colour unaltered, to other liquors.

In this state, the Colouring Particles *reflect no colour*, and, as no light is transmitted through them, they are *black*.

Amongst the liquors, which I evaporated, were the tinctures, and infusions, of the colouring particles of red, purple, blue, and yellow flowers, of logwood, brazil, fustic, turmeric, red saunders, alkanet, sap green, kermes, and all the other Transparent Coloured Liquors, enumerated in the preceding table, which are capable of being reduced to a solid consistence, without undergoing such changes, during their evaporation, as render them opake.

The opacity, which some liquors are apt to acquire from the loss of part of their solvents, arises from various causes, such as the crystallization of saline matters, or the coalescence of the colouring particles, into masses which differ considerably, in density, from the menstrua in which they were dissolved.

The consideration of this subject is of much importance to the art of dying. I have constantly

ſtantly obſerved, that whenever colouring particles become opake, their ſize renders them incapable of entering the pores of wool, ſilk, cotton, or linen, or of cohering to their ſurface. For, the attractive force, by which particles tend mutually to each other, and cohere, is weakened, in proportion as their bulk increaſes, ſo that the degree of magnitude of the colouring particles, which is eſſential to the opacity of liquors, is inconſiſtent with the minuteneſs, requiſite to thoſe means of union, by which dying is effected.

I ſhall ſelect one inſtance, from amongſt many which are applicable to theſe obſervations. I infuſed, in a pint of diſtilled water, ſuch a quantity of fuſtic, that the water was ſaturated with its colouring particles. The aqueous part of this infuſion was evaporated by a gentle, but continued, heat, till it was reduced to a ſolid maſs.

The liquor, during every part of this proceſs, continued tranſparent, and the ſolid extract, which it yielded, tranſmitted a yellow colour, when ſpread thin, but appeared *black*, when thicker maſſes were viewed.

Having prepared another pint of the ſame infuſion, I evaporated half of the water, and left the remainder, till it was cold. In this ſtate it became turbid, and opake. When this liquor was filtered, a tranſparent infuſion paſſed through the filter, and an opake fecula was retained by

the filter, which was afterward dried, and appeared to be a white powder, ſlightly tinged with yellow. This powder did not cohere to the filtering paper, but was eaſily ſeparable from it. It was again ſoluble in water, and formed with it a liquor, in all reſpects, ſimilar to the original infuſion.

From theſe circumſtances, it appears that a given proportion of water, or a ſufficient degree of heat, is requiſite to the ſolution of the colouring particles of fuſtic. And experience evinces that thoſe particles, which are too groſs to paſs through filtering paper, are incapable of entering the pores, or firmly cohering to the ſurface of bodies.

Many dying ingredients, ſuch as the colouring particles of logwood, kermes, and various other matters, are ſoluble in water, in all proportions, and therefore their infuſions are not ſubject to become turbid, or opake, during their evaporation. And the ſolid extracts, obtained from theſe liquors, reflect no colour, but are *black*.

I alſo formed ſolid maſſes, by mixing with a ſmall quantity of drying oil, pigments, which conſiſt chiefly of colouring matter, unmixed with opake ingredients, ſuch as indigo, Pruſſian blue, and ſap green. Theſe paints exhibit their reſpective colours, when thin plates of them are viewed by tranſmitted light; but appear entirely *black*,

black, when the tranfmitted light is intercepted, or when the maffes are of a fufficient thicknefs.

Several fruits and berries, as black cherries, black currants, blackberries, and many others, afford inftances of blacknefs arifing from the denfe ftate of the colouring matter. Their juices are red, when fpread thin on a white ground, or otherwife viewed by tranfmitted light.

Thus it appears, from all the preceding experiments and obfervations, that Tranfparent Coloured Matter, whether diffufed through colourlefs pellucid media, or condenfed into folid maffes, feparate and unmixed, is not endued with any reflective power.

I fhall proceed to confider the action, and properties, of the colouring particles of *opake* coloured bodies, and the means by which their colours are produced.

The tranfparent liquors and glaffes, which have been already examined, owe their colours to fuch particles extracted from opake fubftances: and it has been fhewn that thofe particles do not act upon light by reflection.

It has alfo been obferved, that when coloured particles are fpread thin upon any white ground, they exhibit their feveral colours, by tranfmitting the light reflected from the white ground.

I fhall endeavour to prove, by feveral experiments and obfervations, that the colours of opake bodies are produced by a fimilar operation.

 Amongft

Amongſt the natural bodies, which are the objects of this inquiry, vegetables claim our principal attention, from the great variety and brightneſs of their colours.

In order to examine the leaves, fruits, flowers, wood, and roots of plants, I found it neceſſary to ſeparate their component parts, on which their colours depend.

The following experiments, made with this view, have enabled me to diſcover the cauſe of thoſe colours, and the manner in which they are produced.

I digeſted, in rectified ſpirits of wine, graſs and other *green* leaves of plants: by this means a tranſparent green tincture was obtained, which conſiſted of the colouring matter, diſſolved by the ſpirit. I filled one of the vials, (No. 28.) with this liquor, and viewing that part of it which was in the neck of the vial, I obſerved that it *tranſmitted* a vivid green colour; but the other part of the tincture, which was contiguous to the uncovered ſide of the vial, reflected no light, and conſequently appeared *black*.

I poured, into a white china cup, a ſmall quantity of this tincture, which, by its preſence, imparted to the bottom of the cup a green colour, exactly reſembling that of the leaves from which the matter had been extracted.

After the Colouring Matter had been taken from the leaves, the leaves remained apparently unaltered

unaltered in texture, and in every other reſpect, except in their loſs of colour.

In this ſtate, they conſiſt principally of the fibrous and vaſcular parts, and are either perfectly *white*, or have their *whiteneſs* ſlightly tinged with brown.

I digeſted alſo in rectified ſpirit of wine, red, purple and blue flowers. All theſe yielded, to the ſpirit, their colouring matter, and by the deprivation of it appeared *white*. From moſt of theſe flowers, the ſpirituous menſtruum acquired either no colour, or only a faint tinge. But, when it was acidulated, it became red, and, by the addition of an alcali, aſſumed purple, blue, and green, colours. In each of theſe ſtates, the coloured tinctures were examined in the vials, as in (No. 21, 24, 25.) and, alſo were poured upon a white ground. All of them, by theſe means, were found to yield bright colours by tranſmiſſion, but none of them reflected any light.

I alſo digeſted red, purple and blue flowers, in water ſlightly acidulated with nitrous acid, and thus obtained from them red infuſions, which I have been able to preſerve many years, without the leaſt alteration in their colour, by ſaturating them with ſea-ſalt. (No. 22, 23.)

By the addition of very ſmall portions of alcali, theſe red liquors alſo were changed to purple, blue, and green. All theſe coloured infuſions

were viewed, in the ſame manner as the preceding liquors, and were found to yield vivid colours by *tranſmiſſion,* but to *reflect no colours,* (No. 25.)

The addition of the alcali muſt be very gradual: for if too much is added, at once, to the red liquor, the intermediate colours, between the red and the green, will be wanting. To half an ounce of the red infuſion, it is proper to add, at once, only the leaſt quantity of a ſolution of pearl aſh, that can be taken up, upon the point of a pen, repeating this addition, ſlowly till each of the colours are produced.

The flowers, after having been repeatedly macerated in acidulated water, loſt their colouring matter, and became *white.*

Yellow flowers alſo communicated their colours to water, and to ſpirit of wine. The infuſions and tinctures of theſe flowers were ſubjected to the ſame experiments, as had been employed in the examination of the liquors already mentioned, and appeared yellow by *tranſmitted* light, but *did not reflect any colour.* (No. 26, 27.)

White paper, and linen, may be tinged, by dipping them in the infuſions of the flowers of each colour: and by ſpreading, upon thoſe *white* grounds, the expreſſed juices of ſuch flowers, their colours may be communicated to the paper, and the linen.

Theſe

Theſe means of tinging are ſomewhat ſimilar to the application of vegetable dyes to linen, and of tranſparent water colours to paper, many of which conſiſt of the Colouring Matter of plants, ſuch as indigo, litmus, ſap green, gamboge, the vegetable lakes, and various others.

Theſe operations are ſo well known, and the methods of executing them are ſo obvious, that I ſhould not here have noticed them, if they had not led me to ſome obſervations reſpecting the *white* grounds, on which the colours are applied.

The conſideration of thoſe *white* ſubſtances affords much inſight, into the manner in which the natural colours of vegetables are produced.

I have already ſhewn that, when the Colouring Matter of plants is extracted from them, the ſolid fibrous parts, thus diveſted of their covering, diſplay that *whiteneſs*, which is their diſtinguiſhing character.

White paper, and linen, are formed of ſuch fibrous vegetable matter; which is bleached, by diſſolving and detaching the heterogeneous coloured particles.

When theſe are dyed, or painted, with vegetable colours, it is evident that they do not differ, in their manner of acting on the rays of light, from natural vegetable bodies: both yielding their colours by *tranſmitting* through the

Tranſparent Coloured Matter, the light which is reflected from the white ground.

For it appears, from the preceding experiments, that *no reflective power* reſides in any of their component parts, except in their *white matter* only.

This white matter frequently exiſts, without any conſiderable mixture, in plants, while they are in a ſtate of vegetation: as in cotton, white flowers, the pith, wood, ſeeds, roots, and other parts, of ſeveral kinds of vegetables.

When decayed trees, and other plants, have been long expoſed to the weather, after they have ceaſed to derive nouriſhment from the earth; their coloured juices are apt to be exhauſted by the action of the rain, air, and ſun; by which means the remaining ſubſtance becomes perfectly bleached.

The *white matter* of all vegetables is compoſed principally of an earth. Their aſhes conſiſt of this earth, ſeparated from the inflammable, and evaporable parts, to which they owed their colours.

I have rendered aſhes intenſely white, by carefully calcining them; and afterwards grinding them with a ſmall proportion of nitre, and expoſing this mixture to ſuch a degree of heat, as cauſed the nitre to deflagrate with the ſmall particles of coal which remained unburnt; and laſtly, by diſſolving, in marine acid, the

ferruginous

ferruginous matter diffuſed through them, and repeatedly waſhing the remaining aſhes in a ſufficient quantity of water.

By mixing aſhes, thus purified, with glaſs, together with an additional portion of borax, I obtained an opake enamel remarkable for its whiteneſs.

From all theſe premiſes it appears, that the earth, which forms the ſolid ſubſtance of plants is *white*; that it is ſeparable from the colouring matter by ſeveral means; that, whenever it is either pure and unmixed, or diffuſed through tranſparent colourleſs media, it exhibits its *whiteneſs*; *and is the only vegetable matter which is endued with a reflective power.*

I have hitherto deſcribed ſeveral caſes, in which the *white matter of plants* may be brought to view, by the removal of the coloured particles which covered it. Its expoſure may alſo be effected by other means.

It is well known that the vapour of burning ſulphur whitens red roſes. This effect is generally attributed to the vitriolic acid ariſing from the ſulphur. But ſuch an explanation is certainly erroneous, becauſe the vitriolic acid, applied to the roſes thus whitened, reſtores their red colour.

As ſulphur is compoſed only of phlogiſton and vitriolic acid, and as the whiteneſs is not cauſed by the acid, it is evident that it is effected by the phlogiſton.

I expoſed

I expofed feveral forts of red, and purple flowers to the phlogiftion, difengaged from hepar fulphuris decompofed by an acid, and to other phlogiftic vapours, all of which whitened the flowers. I reftored the red colour of each of thefe, by applying to them indifcriminately either vegetable, or mineral, acids.

It appears, from thefe experiments, that the colouring matter of the flowers is not difcharged or removed, but only diffolved, by the phlogifton; and thereby divided into particles too minute to exhibit any colour. In this ftate, together with the vegetable juice in which they are diffufed, they form a colourlefs tranfparent covering, through which the *white matter* of the flowers is feen untinged.

The Colouring Particles of plants confift principally of inflammable matter; and their folubility in phlogifton, and union with it, are analagous to the mutual action, which other inflammable bodies exert on each other. Thus, æther diffolves all effential, and expreffed oils, animal empyreumatic oils, and refins. Sulphur, camphire, and almoft all fubftances abounding in phlogifton, are foluble in oils, ardent fpirits, or other inflammable menftrua.

The manner, in which the red colour of the flowers is reftored, appears to me to be explicable from known chemical laws. When acids are applied to the whitened flowers, by their ftrong affinity

affinity with the phlogifton which the fulphur had communicated, they unite with that principle, and difengage it from the colouring particles; which, being thus extricated, refume their original magnitude, and colour.

Fixed alcali, whofe affinity alfo with phlogifton is very great, changes the whitened flowers to purple, blue, and green, which colours alcali always produces in fuch flowers.

The matter of light acts upon coloured bodies, in the fame manner as the phlogiftic vapours, whofe operations have been here explained. Thus dyed filk, or other ftuffs, expofed to the fun's light, are deprived of their colour, in every part, which lies in the direction of the rays, whilft thofe parts preferve their colour, which are defended from the accefs of the rays by their folds, or by the intervention of any opake body which intercepts the light.

The colours, thus impaired by the action of phlogifton or of light, may be reftored by the means already defcribed, if they are applied whilft the folution of the colouring particles is recent: but, afterward they are apt to fly off, and be entirely diffipated, on account of the volatility, which the inflammable principle conftantly imparts to matter, with which it is united.

The action and properties of phlogifton, and of the fun's light, are fo exactly fimilar, that the identity

identity of those subtile principles can scarcely be doubted.

White metallic calces, such as the magistery of bismuth, and the crystals and solutions of silver, mercury, and lead, are turned black by the inflammable principle, which they acquire from the sun's light, as well as from phlogistic vapours. And calcined ferruginous earths, which do not obey the magnet, become subject to its attraction, after they have been impregnated with phlogiston, by light collected in the focus of a burning glass.

It is certain that vegetables receive, from the rays of light, all that store of inflammable matter with which they are so richly supplied.

This principle cannot be furnished by the earth, as the small quantity of it, which the soil contains, is inadequate to the effect: and even this small portion is produced from the decomposition of vegetables, or animals which have derived their nourishment from vegetables. Plants which, during their growth, are excluded from the solar light, abound in aqueous juices, but are deficient in oils, and other phlogistic products: and the privation of their other qualities, such as odour, taste, and colour, shews that the matter of light is essential to the vigour and perfection of vegetable substances.

Sir Isaac Newton was of opinion that "Gross "bodies and light are convertible into one ano- "ther, and that bodies receive much of their

"activity

" activity from the particles of light which enter " their compoſition."

He obſerves that " Bodies and light act mu- " tually upon one another, that is to ſay, bodies " upon light in emitting, reflecting, refracting " and inflecting it, and light upon bodies by " heating them, and putting their parts into a " vibrating motion wherein heat conſiſts."* And that the mutual action between light and inflammable bodies is much ſtronger, than between light and other bodies.

In claſſing ſeveral kinds of bodies, according to their refractive powers, he inſtances " Selenite, " rock cryſtal, iſland cryſtal, vulgar glaſs, and " glaſs of antimony, which are terreſtrial ſtony " concretes."† To theſe ſubſtances which conſiſt principally of earth, and have the weakeſt refractive powers, he thus oppoſes the following inflammable ſubſtances; " The refraction of camphire, " oil olive, linſeed oil, ſpirit of turpentine and " amber, which are fat,‡ ſulphureous, unctuous " bodies, *and a diamond, which probably is an* " *unctuous ſubſtance coagulated,* have their refrac- " tive powers in proportion to one another as

* Newton. Opt. Qu. ad Calc.

† Ib. L. II. Part. III. Prop. X.

‡ Sir Iſaac Newton, according to the cuſtom of his time, uſes the word ſulphureous, unctuous, &c. to ſignify what later chymical writers expreſs by the terms phlogiſtic or inflammable.

" their

" their densities without any considerable varia-
" tion. But the refractive powers of these unc-
" tuous substances, are two or three times great-
" er, in respect of their densities, than the refrac-
" tive powers of the former substances in respect
" of theirs."

The clear conceptions which Sir Isaac Newton had formed, respecting the refractive power of the inflammable principle, afford an instance of unparalleled penetration and discernment.

Diamonds, from their apparent resemblance to crystalline vitrifiable stones, and gems, were universally held, by naturalists and lapidaries, not to have differed in their constituent matter, from such stones and gems, except in a greater degree of purity.

Sir Isaac Newton, judging of diamonds by their refractive power, classes them with inflammable bodies, and as they are endued with the strongest refractive power, he does not scruple to rank them at the head of the inflammable bodies, as consisting of the purest phlogiston.

This remarkable observation has not, I believe, ever been noticed, by philosophers, or naturalists, as an object of their consideration: doubtless, because they were prejudiced by the apparent qualities of diamonds, and their resemblance to those of other gems, which seem to have with-held their attention from the powers and properties, the discovery of which was drawn from the more certain test of optical investigation.

After

After Sir Iſaac Newton had publiſhed his Optical Works, almoſt a century had paſſed, during which no experiments were made, whereby the conſtituent matter of diamonds could be aſcertained. Several eminent chymiſts, and philoſophers, in France, have recently applied great ſkill and induſtry in the examination of that ſubject.

From their inquiries, it appears that diamonds, when enveloped in powdered charcoal, and incloſed in crucibles carefully luted, reſiſt the force of fire, and remain unaltered, in the ſame manner as charcoal, and other ſolid inflammable bodies.

When expoſed, under a receiver, to the focus of a large burning glaſs, they impart phlogiſton to the air which is contained in the receiver.

When placed, under a muffle, upon a cupel or ſtand of white calcined refractory earth, in a degree of heat ſufficient to melt pure ſilver, the diamonds ſend forth a continued flame, and thus entirely burn away.

When expoſed to the fire, in thick veſſels of white porcelain, perfectly cloſed with ſtopples of the ſame ſubſtance, ſo that their cavities contain only air and the incloſed diamonds, they are entirely diſſipated, and diſappear, without leaving the leaſt trace of the matter, of which they were formed.

Theſe experiments prove, that diamonds conſiſt of phlogiſton; and they are the only natural ſubſtance,

ſtance, in which that principle appears to exiſt pure and unmixed. For all inflammable liquors contain water: and all ſolid inflammable bodies leave a reſiduum of aſhes, or coal, accordingly as they are burnt in open, or in cloſe veſſels.

Nor can any conſtituent parts of bodies paſs through ſolid ſubſtances, except only phlogiſton, and light. And from their agreement in this reſpect, the identity of theſe ſubtile principles is farther confirmed.

From the native form, and conſtituent matter of diamonds, may they not be properly defined *cryſtallized phlogiſton?*

The chemical experiments, reſpecting the inflammable nature of diamonds, carry with them the greater clearneſs and conviction, as the philoſophers, who made them, were entirely unprejudiced in their inquiries on that ſubject: for they do not ſeem to have been aware that Sir Iſaac Newton had diſcovered, from optical obſervation, the ſame truth to which they were led by the chymical phænomena.

The ſolvent power of phlogiſton, whether obtained from terreſtrial bodies, or proceeding immediately from the light of the ſun, is manifeſt in various inſtances ſimilar to thoſe which have been hitherto explained.

Silk is whitened by the phlogiſtic vapours of ſulphur: and this operation does not appear to differ

differ from the change effected in flowers by the ſame vapour.

The light of the ſun is found to be a neceſſary, and eſſential, agent in bleaching linen, bees' wax, and various other ſubſtances. Some part of the colouring matter, which impairs the whiteneſs of ſuch bodies, not yielding to the power of any other ſolvent.

Red flowers are whitened by the electric ſpark, of whoſe inflammable nature we cannot entertain the leaſt doubt. For the ſpark itſelf is a bright flame, and it yields the ſame ſmell, which all other phlogiſtic matters impart.

The electric ſpark, in like manner changes the blue infuſion of turnſol, to red. The effects which it produces on the turnſol, and on red flowers, do not differ from each other, except in degree only. For, when vegetable matter is diſſolved, it is changed from blue, to red; and when it is farther diſſolved, it is divided into particles too minute to exhibit any colour.

A due attention to the changes of colour, and other effects, ariſing from the ſolvent power of phlogiſton, will afford much inſight into ſeveral operations of the arts and manufactures, and will furniſh an explanation of many appearances, which occur in chymiſtry, and phyſics, which cannot otherwiſe be rightly underſtood.

The perfection of the arts of dying, and bleaching, and of preparing and preſerving painters'

 colours,

colours, essentially depend on the knowledge of this subject.

Solutions effected by means of phlogiston, frequently are wrongly attributed to the operation of supposed acid menstrua: as several kinds of substances are capable of being dissolved indiscriminately, either by acids, or phlogiston.

For the purpose of distinguishing, in any instance, between the action of the acid solvents, and that of the inflammable menstrua, it is proper to examine the nature of the matter, by which either of those principles is furnished.

Fixed air is generally supposed to possess an acid quality, and several of its properties are ascribed to its acidity.

The change of colour, produced in vegetable juices by the electric spark, is adduced as a proof of the acidity of fixed air. But it has been already shewn that this effect does not arise from acid, but from phlogistic, matter.

The acid quality of fixed air is also generally inferred, from its power of dissolving iron. But, phlogiston also is a solvent of iron. Thus, a considerable portion of that metal is always dissolved and held in solution, by the phlogisticated alcaline lixivium, which consists of inflammable matter calcined with fixed alcali. M. Margraf has shewn that several other metals are soluble in this lixivium. Hence it is evident that the solubility of iron does not prove the acidity of the solvent, but may arise from the phlogiston contained in it.

Fixed

Fixed air, by its combination with alcalies, diminishes their causticity, and promotes their crystallization. These properties are also supposed to be communicated by an acid, imparted by fixed air.

But, this hypothesis does not agree with the effects, which are produced by the combination of acids with alcalies. For, neutral salts are formed by the addition of acids to alcalies. And as alcalies do not become neutral salts, by their union with fixed air, but are only changed thereby, from caustic and deliquescent, to mild alcalies, capable of crystallizing, it is evident that the alteration, which fixed air causes in them, does not result from the introduction of an acid.

We must, therefore, turn our views to the consideration of some other principle, by which these effects may be produced.

It appears from various chymical processes, that alcalies are rendered mild, and capable of crystallizing, in proportion as they are united to phlogiston. The phlogisticated alcaline lixivium, when saturated, is perfectly mild, and, by a slight evaporation, is reduced to a concrete crystalline mass, which does not deliquesce, or imbibe the least moisture from the air, and no longer retains any alcaline character or property.

M. Beaumé, by an elegant and ingenious experiment, has proved the presence of phlogiston in mild alcalies, and has shewn that their power

of cryſtalling depends upon their union with that principle.

He heated, in a ſilver veſſel, a lixivium of mild alcali, which imparted to the ſilver a covering, or coating, of inflammable matter, by which its ſurface was tarniſhed, and became black. The lixivium was ſeveral times poured out of the ſilver veſſel, and after the ſurface of the ſilver had been freed from the tarniſh, the lixivium was replaced in it, and again heated, by which the tarniſh was renewed. This was repeated till the lixivium no longer communicated any ſtain to the ſilver.

The cauſticity of the lixivium increaſed, in proportion as it imparted its phlogiſton to the ſurface of the ſilver, and, at the end of the proceſs, the alcali became perfectly cauſtic, and incapable of cryſtallizing.

Theſe inſtances, and many others which might be adduced, ſeem to prove that the change, which fixed air produces in cauſtic alcalies, is not effected by acid, but by phlogiſtic matter.

It is certain that the matter, communicated to lime by fixed air, is the very ſame which it imparts to alcalies. For it may be transferred, unchanged, from one of thoſe ſubſtances, to the other; and, when united to either of them, ſtill retains the ſame *qualities*. Therefore, if phlogiſton renders alcalies mild, and effects their cryſtallization, the ſame principle alſo precipitates lime, and,

and, in like manner, reſtores it to its ſtate of mild calcareous earth.

The experiments and obſervations, on which Dr. Black has eſtabliſhed his comprehenſive and conſiſtent theory, clearly prove, that lime is precipitated from lime water, by fixed air: but his views were not extended to an inveſtigation of the particular matter, or quality, whereby fixed air operates that effect.

Lime which has been precipitated from lime water, and reſtored to the ſtate of a mild calcareous earth, is again ſoluble by the addition of a larger proportion of fixed air. This ſolution is attributed to the acid quality of fixed air; and it has been conſidered as a ſtrange and extraordinary circumſtance, that accordingly as different proportions of it are applied, it ſhould act as a precipitant, and a ſolvent, of the ſame ſubſtance.

The ſimplicity, which nature obſerves in all her operations, will not permit us to ſuppoſe, that fixed air is poſſeſſed of two different or oppoſite qualities, by one of which it precipitates, and by the other of which, it diſſolves.

The precipitation of lime from lime water, and its reſolution, are effected by an equable uniform action, exercifed by one and the ſame ſimple principle, which is a conſtituent and eſſential part of fixed air. And, ſuch a precipitation, and reſolution, are not extraordinary or complex phænomena, as they have been eſteemed, but are

analogous to the ordinary and conſtant effects, which ariſe from chymical affinities.

This may be exemplified, by any compound which aſſumes a concrete ſolid conſiſtence, by its union with a given quantity of a fluid, and which, by the addition of a larger quantity of the ſame fluid, is reduced to a liquid ſtate.

Thus, when a due proportion of water is added to iron, and vitriolic acid, a mutual attraction takes place between theſe three ingredients, by means of which they are united, and, by their combination, a concrete vitriol, or metallic ſalt, is formed. But, if a greater quantity of water be added to this concrete ſalt, as the mutual attraction, after this addition, ſubſiſts equably between the vitriolic ſalt and the whole maſs of water, the acid and ferruginous particles are more minutely divided, and diffuſed uniformly throughout every part of the water. And thus, the ſolid concrete ſalt is reſolved, and a vitriolic liquor is formed, in which the water predominates.

Lime ſtrongly attracts and unites with inflammable ſubſtances, ſuch as ſulphur, camphire, and reſins. Fixed air has a ſtill greater affinity to lime. Becauſe in all the groſſer ſubſtances, the phlogiſton is allayed by ſalt, earth, and other matters: but, in fixed air, it exiſts in a purer, and conſequently, a more active ſtate.

As alcalies are rendered mild, or cauſtic, by the preſence, or abſence, of the inflammable prin-

ciple,

ciple, it can hardly be doubted that the difference between mild calcareous earth, and quicklime, is alſo occaſioned by a communication, or deprivation, of the ſame principle.

The origin of fixed air, ſeems to prove its phlogiſtic nature. For all bodies, which yield it, afford alſo inflammable matter: but many of them do not yield any acid. Calcareous ſpar, magneſia, and alcaline ſalts, ſend forth fixed air, and all theſe ſubſtances, by the loſs of it, are deprived of their inflammable contents: diamonds, expoſed to the focus of a burning glaſs under a receiver, impart to the air, contained in it, a power of precipitating lime, from lime water, when it is agitated with it. But it does not appear that any acid can be derived from thoſe bodies.

Some of the properties of fixed air are conſiſtent with either the character of acid, or of phlogiſton. Such are, its power of altering the colour of vegetable juices; its affinity to alcalies; and ready union with lime; its power of diſſolving iron, which is inſtanced in all acids, and in the phlogiſticated alcaline lixivium; the antiſeptic quality prevails equally in acids, and in inflammable ſpirits; acids are diſengaged from ſubſtances, which are decompoſed by ſtronger acids, phlogiſton is likewiſe expelled from bodies, which are diſſolved in acids.

The qualities of acid, and phlogiſton, agree in theſe, and in ſeveral other inſtances, but fixed air

is endued with properties, which are peculiar to phlogiſton. Such as its power of effecting the cryſtallization of alcalies, without changing them to neutral ſalts; its tendency to eſcape from water, and its affinity with the air, by means of which a conſiderable quantity of fixed air is united with, and diffuſed throughout, every part of the atmoſphere.

Water, as well as phlogiſton, is a conſtituent part of all ſubſtances which yield fixed air. Both theſe principles have a ſtrong affinity to air. This appears from the union which air forms with the inflammable principle, when it is diſengaged from bodies by combuſtion, fermentation, putrefaction, or any other mode of decompoſition; and from the mutual attraction of water and air, which is manifeſted by evaporation, and by the conſtant preſence of aqueous particles in the atmoſphere.

The laws of chymical analyſis will hardly permit us to doubt, that the air, which is obtained from mild alcalies, calcareous earth, and various other ſubſtances, receives from them when they are decompoſed, the ſame contents which were united in them as conſtituent parts, while they were in their intire ſtate. And their analyſis invariably ſhews that air, water, and phlogiſton, enter their compoſition.

From hence it ſeems to follow, as an immediate and obvious inference, that fixed air conſiſts of theſe three ingredients, either united in bodies, and

and difcharged from them, already combined, or that it is formed in the atmofphere, by the concurrence and union of thefe principles. And all the phænomena, not only of fixed air, but alfo of phlogifticated air, may be folved by the action, and properties, of thefe ingredients.

The weight of fixed air, indicates that it contains a confiderable portion of aqueous matter; and it is by means of this conftituent principle, that it is mifcible with water, in like manner as ardent fpirits are, notwithftanding their inflammable nature. The phlogiftic part of fixed air has been already confidered.

Phlogiftic matters are mifcible with water, only in proportion as they contain a quantity of the aqueous principle in their compofition. When the relative proportion of this conftituent part, is lefs than that of the phlogifton combined in fuch matters, they are either immifcible with water, or only mifcible in part.

Thus, fpirit of wine, which is oil combined with water, unites with water, in all proportions.

Æther, which confifts of fpirit of wine, from which a confiderable portion of its water has been feparated by the vitriolic acid, is not mifcible with water in all proportions: but, ten parts of water are requifite to the abforption of one part of æther.

Oil, which contains ftill lefs water in its compofition,

pofition, does not, in any degree, mix with water.

Refinous fubftances do not combine with water, becaufe their aqueous part is not in fufficient quantity to ferve, as a medium, for the union of their phlogifton.

In gums, the relative proportion of phlogifton is much lefs than in refins, and that of the water is much greater: and by the intervention of their aqueous part, gums are readily mifcible with water.

Refins, when united with a due proportion of gum, are by its mediation, alfo rendered foluble in water. But, if a lefs proportion of the gum be joined with the refin, only a part of the compound, refulting from this union, is difpofed to mix with water, and a refiduum is left, which is incapable of being diffolved in any aqueous liquor.

Fixed air feems to refemble thefe matters, which do not poffefs a fufficient quantity of the aqueous medium, to render them totally foluble in water. For, after a given portion of fixed air has been imbibed by water, a refiduum remains, which is incapable of being abforbed by it, and is called phlogifticated air.

This air may be formed from fixed air, not only by the fubtraction of water, but by the addition of the inflammable principle: as when phlogifton is communicated to fixed air by electric fparks, or the

the vapours diſengaged from a mixture of ſulphur and iron filings.

The origin of phlogiſticated air ſhews, that its difference, from fixed air, conſiſts chiefly in its deficiency of water.

As metals contain no water, ſo the phlogiſton, which ariſes from them during their calcination, does not produce fixed air, but phlogiſticated air.

But vitriols, and all other ſaline matters, contain water as a conſtituent part, and therefore yield fixed air. Calces of metals alſo, which have received aqueous matter, in the proceſs of their calcination, as white lead, and other calces which have abſorbed water, together with air, from the atmoſphere, alſo yield fixed air.

The fermentation, and putrefaction, of vegetable and animal ſubſtances, is effected by means of their moiſture, and therefore, by theſe modes of decompoſition, fixed air is produced.

Fixed air is more effectually formed by reſpiration, than by many other phlogiſtic proceſſes, in conſequence of the copious ſupply of the aqueous, as well as the phlogiſtic, principle, which the air receives from the lungs.

Fixed air may be formed from vegetable acids, but when it is thus conſtituted, it does not differ from that which is produced from alcalies, magneſia, calcareous ſpar, and various other ſubſtances, which yield no acid. It is therefore evident, that in each of theſe inſtances, it is formed by the

combination

combination of ſome principles, which are common to all thoſe ſubſtances.

Theſe principles are water, and phlogiſton. In vegetable acids, the phlogiſton combined with the water, is equal, in quantity, to that which conſtitutes the inflammable part of ſpirit of wine: for radical, or concentrated, vinegar, is totally inflammable.

The acid ſtate of vegetable matters is not eſſential to them, nor is it requiſite to their production of fixed air. For, fixed air is producible from plants, when they are recent; when they are in a vinous ſtate, and afford ardent ſpirits; and alſo when they are in a ſtate of putrefactive fermentation. From whence it appears that in their acid, as well as in their recent, vinous, or putrefactive ſtate, they yield fixed air, by means of their aqueous, and phlogiſtic, principles.

All fixed air, from whatever ſubject it is procured, or to whatever bodies it is transferred, conſiſts, conſtantly and invariably, of the ſame materials, combined in the ſame proportions: otherwiſe it could not reſtore lime, cauſtic alcalies, or other matters, to their original mild ſtate: becauſe, theſe ſubſtances cannot be recompoſed, but by the ſame proportion of their conſtituent principles, which they contained, before their decompoſition.

Thus, lime cannot be reſtored to the ſtate of mild calcareous earth, by water, or by pure dephlogiſticated

phlogiſticated air, becauſe each of theſe principles conſiſts of only one of the three ingredients, which are requiſite for that purpoſe.

Nor can the recompoſition of calcareous earth be effected by phlogiſticated air, becauſe it contains an exceſs of phlogiſton, and a defect of water.

Compounds, formed of ſuch relative quantities of any of theſe principles, as do not conſtitute fixed air, may acquire a due proportion of them, by an addition of the ingredients in which they are deficient.

Pure dephlogiſticated air is reduced to fixed air, by the communication of aqueous, and phlogiſtic vapours, diſengaged from bodies, by various modes of decompoſition: theſe principles readily combine with air, on account of their great affinity to it.

Phlogiſticated air, when agitated with water, receives into its compoſition a quantity of aqueous particles, ſufficient to conſtitute it fixed air: and by that means, it becomes capable of precipitating lime, from lime water.

If the analyſis, and recompoſition, of calcareous earth be ever ſo often repeated, its analyſis will always yield, and its recompoſition will always require, the ſame relative quantities of air, water, and phlogiſton.

Fixed air therefore, ſeems to conſiſt of theſe three principles invariably, and conſtantly, combined in the ſame proportions.

I ſhall

I ſhall not here enter upon the conſideration of any other aëriform fluids, becauſe they are foreign to my preſent inquiry.

I was led to an examination of the inflammable principle, by the changes, which it operates in coloured ſubſtances, both when it is in a detached and ſeparate ſtate, and when it forms a conſtituent part of fixed air, and is diffuſed throughout the atmoſphere.

Fixed air has been frequently conſidered as a mere compound of air, and phlogiſton. But, ſuch a compound ſeems to approach nearer, in its nature, to phlogiſticated air; as it is deficient in one of the principles, which is eſſential to fixed air.

I have endeavoured to point out ſome qualities of the inflammable principle, which have not hitherto been obſerved, or which have not been applied to the ſolution of the phænomena of elaſtic fluids. Such are, its ſolvent power; its power of effecting the mildneſs, and cryſtallization of alcalies; its ſtrong affinity to calcareous earth, alcalies, and other ſubſtances which yield fixed air, whoſe ſimilar, and correſpondent, properties reſult from the phlogiſton, which it contains as a conſtituent part.

I willingly ſubmit theſe obſervations, to the candid judgment of thoſe excellent philoſophers, who have extended the knowledge of elaſtic fluids, by their inſtructive labours: amongſt which, the

numerous experiments and obſervations of Dr. Prieſtley are the moſt conſpicuous.

From the preceding experiments and obſervations it appears, that the colouring particles of flowers and leaves, are ſoluble in acid, and phlogiſtic, menſtrua.

The other parts of vegetables conſiſt of materials, ſimilar to thoſe which are contained in their flowers, and leaves, and undergo the ſame changes, from the ſame cauſes. I extracted from logwood, its colouring particles, by repeatedly boiling it in water. The wood, thus deprived of its tinging matter, no longer retained its yellow colour, * but was of a brown hue, ſimilar to oak wood.

I macerated ſome pieces of logwood thus deprived of its colour, in aqua fortis, and, after they had undergone the action of that acid, they were waſhed in a ſufficient quantity of water. The wood by theſe means was reduced to *whiteneſs*.

* Moſt authors, who treat of colouring ſubſtances, deſcribe logwood, as a *red* wood. I have never procured logwood which was of any other colour, than *yellow*. It imparts yellow and orange colours to diſtilled water. Other waters extract a red tinge from it, by means of the alcali which they contain. Theſe obſervations are alſo applicable to the other dying woods, to kermes, and various other articles of the materia tinctoria. I ſhall only add that the tinctures, infuſions, and ſolutions, which are enumerated in the preceding table of coloured liquors have been deſcribed from careful and repeated obſervations.

By

By a similar treatment, fustic, and other dying woods, were deprived of their Colouring Matter, and became *white*.

I have hitherto shewn, that the Colouring Matter of plants does not exhibit any colour by reflection, but by transmission only; that their solid earthy substance is a white matter; and that it is the only part of vegetables, which is endued with a reflective power; that the colours of vegetables are produced by the light reflected from this white matter, and transmitted from thence through the coloured coat, or covering, which is formed on its surface by the colouring particles; that, whenever the colouring matter is either discharged, or divided, by solution, into particles too minute to exhibit any colour, the solid earthy substance is exposed to view, and displays that *whiteness*, which is its distinguishing character.

Animal substances do not afford any great variety of coloured products. But, in all those animal matters, which do exhibit colours, the colouring particles are endued with the same properties, and are regulated by the same laws, which prevail in vegetable substances.

The tinctures and infusions of cochineal (No. 59, 60.) and of kermes (No. 61, 62.) yield their colours, when light is transmitted through them, but do not reflect any colour.

The principal animal coloured substances are the bile, and the blood. I diluted, with distilled water,

water, fresh ox gall and examined it, in the vial (No. 63.) that part of it which was in the neck of the vial, and which was viewed by transmitted light, was yellow, the anterior surface reflected no colour, but appeared *black.*

Flesh consists of fibrous vessels containing blood, and is perfectly *white,* when divested of the blood, by ablution. The membranes, sinews, bones, and other solids, are *white,* and when they are freed from their aqueous and volatile parts, they are a mere white earth, unalterable by fire, and capable of imparting to glass an opake whiteness.

Blood, diluted with warm water, was examined, in one of the vials. It transmitted a red colour; its anterior surface was almost, but not entirely, black. For it received a slight mixture of a brown hue, from some particles which were coagulated, and were suspended in the red liquor.

That I might procure blood, sufficiently diluted, and at the same time, perfectly and equably dissolved, I mixed as much red cruor, with spirit of sal ammoniac, as imparted to it a vivid red colour. The liquor, thus composed, was viewed in the vial, (No. 64). That part of it, which was contained in the neck of the vial, transmitted a bright red; that which was viewed through the anterior side of the vial, reflected no colour but was intensely *black.*

From these observations, it appears that the florid red colour of the flesh arises from the light

which is *reflected* from the *white* fibrous ſubſtance, and tranſmitted back through the red tranſparent covering, which the blood forms on every part of it.

The blood, whilſt recently drawn, does not aſſume the appearance which is common to tranſparent coloured liquors, for, ſuch liquors, when too maſſy to tranſmit light from their farther ſurfaces, are black. But blood, recently drawn, yields a red colour, in whatſoever maſſes it is diſpoſed.

The colour, thus exhibited, ariſes from a white matter diffuſed throughout the blood. The white matter is eaſily ſeparable from the red part of the cruor. This may be performed, by dividing the cruor, after it is coagulated, into thin pieces, upon which a ſufficient quantity of water muſt be poured. The cruor communicates a red tinge to the water, which ſhould be changed every day. After a few days, the water no longer receives any tinge, and the remaining maſſes of the cruor are, by theſe means, rendered perfectly *white*.

Thus it appears that not only the fleſh, but alſo the blood itſelf, are white ſubſtances, tinged with red particles.

The red colour, which the ſhells of lobſters aſſume, after they are boiled, is a mere ſuperficial covering, ſpread over the white calcareous earth of which the ſhells are formed, and may be eaſily removed by ſcraping, or filing the ſurface.

Before

Before this ſuperficial covering is attenuated, by the heat, it is much denſer, ſo that, in ſome parts of the ſhells, it appears black: as it is too denſe to admit the paſſage of the light to the white ſubſtance of the ſhell, and back again. But where this tranſparent blue colour is ſpread thinner, and rarer, the light, reflected from the white ſubſtance of the ſhell, is tranſmitted back through the blue film, and yields a light blue colour.

The colour, of the ſhells of ſeveral ſpecies of eggs, is alſo merely ſuperficial, and may be ſcraped off, leaving the white earth of the ſhell expoſed to view.

Feathers, in like manner, owe their colours to thin layers of Coloured Matter, covering the white ſubſtance, of which they are principally formed. I ſcraped off the ſuperficial colour from ſuch parts of vividly coloured feathers, as were ſolid enough to admit of that operation, and, by this means ſeparated the coloured layers from the white ground, on which they had been naturally ſpread.

The ſurfaces of the lateral fibres of feathers cannot be thus ſeparated on account of their minuteneſs. But, as they appear, when viewed in a microſcope, nearly to reſemble, in their form, the feathers themſelves, it ſeems probable that their colours ariſe from a ſimilar matter, and conformation, in the ſmaller fibres, as in the groſſer parts of the feathers.

The colours of all the animal ſubſtances, which have fallen under my obſervation, are effected in

the ſame manner as thoſe of the ſpecimens which I have here deſcribed.

In all theſe inſtances, the colours of the bodies are produced by the light reflected from a white ſubſtance, and tranſmitted back from thence, through a tranſparent coloured covering. The colouring particles have been extracted from ſuch of the bodies, as were capable of yielding them to any proper ſolvents: and in their ſtate of ſolution, as well as when condenſed into a ſolid conſiſtence, they have been conſtantly found to poſſeſs a power of tranſmitting colour, but to be devoid of any reflective power.

In the examination of ſome animal ſubjects, when the colouring matter could not be ſeparated from the white ſubſtance, by chemical means, I have had recourſe to mechanical methods of effecting their diviſion. But, ſuch methods can only be employed, when the principal part of the white ſubſtance is unmixed with the coloured coat or covering, which is ſpread upon its ſurface.

The mineral kingdom affords a great variety of coloured ſubſtances. Theſe conſiſt principally of earthy, and metallic matters.

The earths have been uſually arranged in three claſſes, the ſiliceous, the calcareous, and the argillaceous, which is obtained pureſt in the earth of alum. To theſe, mineralogiſts have lately added magneſia, and terra ponderoſa, which is the baſis of ſpar. All theſe earths are perfectly

white,

white, when pure, and free from heterogeneous matters.

The colours, which they aſſume, are adventitious, and ariſe from phlogiſtic, or metallic, mixtures. Such compounds form ochreous, cupreous, and other metallic earths, and coloured clays, and boles: which may be artificially obtained, by precipitating metals from their ſolutions, and uniting them with calcareous, or aluminous baſes.

Calcareous earth indurated conſtitutes marble, which may be tinged, by means of metallic ſolutions, with dyes which, both in their colours, and materials, are ſimilar to thoſe produced by nature.

From ſiliceous earths, flints are formed, which owe their colour to phlogiſton, and when ſufficiently heated, are rendered white, by the loſs of their inflammable contents.

Siliceous earths impregnated with metals, form agates, cornelians, jaſper, and coloured cryſtals.

The emerald, ſapphire, topaz, hyacinth, and ruby are compoſed of a mixture of ſiliceous, calcareous, and argillaceous earths, and receive their colours from iron.

All theſe coloured ſtones may be imitated by glaſſes tinged with ſuch phlogiſtic, or metallic matters, as enter the compoſition of the original ſubſtances.

Liquors, impregnated with phlogiſton (No. 65, &c.) tranſmit coloured light, but do not reflect any colours. Nor do the glaſſes which derive their colours from inflammable, or metallic matters, appear coloured by reflection, but by tranſmiſſion only.

From hence it is evident, that phlogiſtic, or metallic matters, when united with earths, do not reflect the coloured light: but are tranſparent coloured media, which tranſmit the light reflected by the particles of the white earths.

Metals, when in their entire metallic ſtate, are endued with a ſtrong reflective power. All the metals, except gold and copper, act equally upon all the rays of light, from which their whiteneſs ariſes.

Gold exhibits a white light, which is *tinged with yellow*. I have uſed this expreſſion, becauſe it appears, from experiment, that gold reflects a white light, and that its yellow colour is a tinge, which is ſuperadded to its whiteneſs. The experiment is thus ſet forth by Sir Iſaac Newton.*
"Gold in this light, (that is, a beam of white
"light) appears of the ſame yellow colour as in
"day light, but by intercepting at the lens a
"due quantity of the yellow making rays, it
"will appear white like ſilver, as I have tried,
"which ſhews that its yellowneſs ariſes from the

* Newton. Opt. L. I. Part II. Prop. XI. Prob VI.

"exceſs

"excefs of the intercepted rays tinging that "whitenefs with their colour, when they are let "pafs."

I have already fhewn, by numerous experiments, in what manner coloured tinges are produced; and it uniformly appears, from all thofe experiments, that colours do not arife from reflection, but from tranfmiffion only.

A folution of filver is pellucid and colourlefs. A folution of gold (No. 18.) tranfmits yellow, but reflects no colour. This metal alfo when united with glafs, yields no colour by reflection, but by tranfmiffion only.

All thefe circumftances feem to indicate, that the yellow colour of gold arifes from a yellow tranfparent matter, which is a conftituent part of that metal, that it is equably mixed with the white particles of the gold, and tranfmits the light which is reflected by them. In like manner as when filver is gilt, or foils are made by covering white metals with Tranfparent Colours.

But, thefe factitious coverings are only fuperficial, whereas the yellow matter of gold is diffufed throughout the whole fubftance of the metal, and appears to envelop and cover each of the white particles.

In whatfoever manner the yellow matter of gold is united to its white fubftance, it exifts in a rare ftate. For it bears only the fame

proportion to the white particles of the gold, as that part of the yellow-making rays, which were intercepted, bears to all the other rays comprized in the white light of the sun.

Calces are metals, divested of their phlogistic principle, by menstrua, or by fire. The calcined particles are suspended in their solvents, and, together with them, form transparent liquors. The metals, thus dissolved, reflect no colours, but either transmit coloured light, or are pellucid and colourless.

It is proper here to explain the cause, why the metallic particles, which yield no colour, by incident light, when suspended in their solvents, are disposed to exhibit colours, when separated from their menstrua, and reduced to a calciform state.

Sir Isaac Newton has shewn, that when spaces, or interstices, of bodies are replenished with media of a different density, the Bodies are Opake; that those superfices of transparent bodies reflect the greatest quantity of light, which intercede media that differ most in their refractive densities; that the reflections of very *thin Transparent Substances* are considerably stronger, than those made by the same substances of a greater thickness.

On these grounds, the minute portions of air, or of the rarer medium, which occupies spaces void of other matter, reflect a vivid *White Light*, whenever their surfaces are contiguous to media, whose densities differ considerably from their own. So

that,

that, every ſmall maſs of air, or of the rarer medium, which fills the pores, or interſtices, of denſe bodies, is a minute white ſubſtance.

This is manifeſt, in the whiteneſs of froth, and of all pellucid Colourleſs Bodies, ſuch as glaſs, cryſtal, or ſalts, reduced to powder, or otherwiſe flawed. For, in all theſe inſtances, a *White Light* is reflected from the air, or rarer medium, which intercede the particles of the denſer ſubſtances, whoſe interſtices they occupy.

All pellucid Colourleſs Subſtances become opake and white, by the admixture of pellucid colourleſs media of conſiderably different denſities: as in the inſtances which have been here adduced. And all Opake White Subſtances are rendered pellucid and colourleſs, by reducing them to uniform maſſes, whoſe component parts are, every where, of nearly the ſame denſity. Becauſe, all reflections are made at the ſurfaces of bodies differing, in denſity, from the ambient medium; and, in the confines of equally denſe media, there is no reflection.

Thus, opake white earths are reducible to Pellucid Colourleſs Glaſſes, by proper fluxes, and a ſufficient degree of heat. When the particles of air and water, united in the ſmall bubbles of which white froth conſiſts, are ſeparated from one another, each of them conſtitutes an uniform, Pellucid, Colourleſs Subſtance.

When

When particles of air, or of the rarer matter, occupy the interftices of any denfe *Tranfparent Coloured Body*, the *White Light* reflected from thofe rare fubftances fhines through the Tranfparent Coloured Medium which the particles intercede, and is tinged by it, according to the colour which it tranfmits.

Thus, an infufion of cochineal tranfmits a red colour, and its furface is *black*, when viewed by incident light. But, if this liquor be agitated, its furface is thereby covered with a red froth, whofe colour is occafioned by the light, reflected from the globules of air inclofed in each of the bubbles, and tranfmitted back through the tranfparent films of red liquor, which cover them.

I tinged feveral maffes of glafs with metals fo intenfely, that they appeared *black*, except in fuch parts as, from their thinnefs, tranfmitted the Coloured Light. Pieces of thefe glaffes were pulverized feparately, and each of the powders, thus prepared, exhibited the refpective colours, with which the feveral maffes of glafs had been tinged.

The action of fuch powders, on the rays of light, arifes from the difcontinuity of their parts, whereby the air is admitted into their interftices, and, by its reflective power, produces thofe appearances, which refult from rare media contained

tained in the pores of Tranſparent Coloured Subſtances.

It is evident that calces, ſeparated from metallic ſolutions, derive their power of exhibiting Coloured Light from the ſame cauſes, which prevail in thoſe inſtances which I have here adduced, and explained. For, in proportion as the interſtices of the calces are evacuated, by the deprivation of their liquid ſolvents, the air pervades thoſe vacuities.

Vitriols, and other metallic ſalts, are formed from metallic ſolutions, by the evaporation of their aqueous part, excepting only ſuch a portion of it as is eſſential to their cryſtallization.

Theſe metallic ſalts are either coloured, or colourleſs, according to the ſolutions from which they are formed. Whilſt their conſtituent principles remain united in due proportion, and order, they are pellucid. But when their watery part is diſengaged, they loſe their tranſparency, and texture, and are reduced to an opake friable maſs, or to powder.

In this ſtate, air pervades the interſtices which the water had evacuated, and reflects a white light, in conſequence of the difference of its denſity from that of the matter which is contiguous to it; and as even the coloured vitriols, and other coloured metallic ſalts, contain a large proportion of colourleſs ſaline matter; when the water of their cryſtallization is expelled, their metallic

metallic coloured particles are ſo diluted, that the maſs appears almoſt white.

Theſe effects are alſo produced by pulverizing, or otherwiſe flawing, metallic ſalts, but not ſo compleatly as by the expulſion of their water.

By calcination, the ſaline matter is driven off: and, when this operation is effectually performed, the calces conſiſt of metallic particles, which are free from all extraneous matter, excepting only the moleculæ of air which occupy their interſtices.

The air, which intercedes the particles of metallic calces, reflects the light more ſtrongly than that which intercedes vitriolic particles. Becauſe the calces of metals differ more, in their denſity, from air, than metallic ſalts differ from that fluid. Therefore, each molecula of air, which intercedes the metallic particles, powerfully reflects a white light, and conſequently is itſelf a minute white body, ſuch as is ſeen in the globules of air enveloped in the ſmall bubbles of water which conſtitute white froth.

But, as the ſpecific denſity of metallic calces greatly exceeds the ſpecific denſity of water, the moleculæ of air, which intercede the metallic particles, reflect the light ſtronger than thoſe which intercede the aqueous particles, in proportion to their difference of denſity with reſpect to that of the ambient ſubſtances, whoſe vacuities they occupy.

No

No ſubſtances, whoſe interſtices are occupied by air, differ more from air, in their ſpecific denſity, than metallic calces do. For which reaſon, the reflections made at the ſurfaces, which intercede thoſe media, are extremely ſtrong.

The Light, reflected from the moleculæ of air contained in the interſtices of metallic calces, is tranſmitted through the thin Tranſparent Matter of the calces which cover them, and is thereby tinged, according to their reſpective colours.

It is evident that calces, obtained from Tranſparent Metallic Solutions, by the evaporation and expulſion of their aqueous, and ſaline, parts, conſiſt of Tranſparent Matter: for, the metallic particles in the ſolutions, and in the calces, are the ſame, and the opacity, or tranſparency, of the ſolutions, and calces, ariſe from the difference of the media, which intercede the metallic particles in the one, or the other, of thoſe ſtates.

Calces, united with pellucid colourleſs glaſs, are tranſparent; and metallic glaſſes, which are formed by fuſion of the calces, are alſo tranſparent. For they conſtitute ſolid, ſmooth, maſſes, devoid of ſuch pores as are capable of admitting the entrance of air.

The exiſtence of air, in the calces of metals, is clearly eſtabliſhed by numerous chymical experiments. From theſe it appears, that metals, during their calcination, copiouſly abſorb the ambient

ambient air, and thereby acquire a confiderable increafe of weight. When they are again reduced to their metallic form, a quantity of air, equal to that which was acquired during the calcination, is difengaged, and the mafs lofes the adventitious weight, which it poffeffed during its calciform ftate.

Metals, calcined by heat only, act upon light in the fame manner as thofe which have been previoufly diffolved, and afterward calcined. They agree, in the difcontinuity of their particles; in their abforption of air, and their confequent increafe of weight; and in their tranfparency, which is manifefted, when they are mixed with pellucid glafs, or other pellucid media, and when tranfparent metallic glaffes are produced by their fufion.

Metallic precipitates, which are combined with fome of the matters, by which they were diffolved, or precipitated, tranfmit the light which is reflected by thofe matters. When precipitates are difengaged from fuch extraneous parts, by ablution, calcination, or any other means, they are mere calces, fuch as have been already confidered.

When oil, inftead of air, is interpofed between the particles of paints which are formed of the denfer metals, fuch as vermilion, and minium, their colours are not perceptibly altered: becaufe, although oil confiderably exceeds air, in

its

its ſpecific denſity, yet as it differs greatly in that reſpect, from the denſer metallic powders, the moleculæ of oil, which intercede their particles, act upon the incident light ſo ſtrongly that the reflections, effected by them, cannot be diſtinguiſhed from thoſe which are cauſed by rarer media.

When ochres, and other paints, which owe their colours to the rarer metals, are combined with oil, they aſſume a darker hue. Becauſe the exceſs of the denſity of oil, over that of air, forms a ſenſible difference, when comparatively conſidered, with reſpect to the ſpecific gravity of the rarer metals. From this cauſe, perceptibly leſs light is reflected from the moleculæ of oil, than from thoſe of air, and conſequently the maſs appears darker.

When air is expelled from, and oil is united with, coloured powders, whoſe ſpecific denſity is much leſs than that of metallic calces, the brightneſs of their colours is diminiſhed in proportion as the powders approximate, in ſpecific denſity, to the media which occupy their interſtices. And when the ſpecific denſity of theſe is nearly equal, there is no ſenſible reflection in the confines of their reſpective ſurfaces, and therefore the maſs appears black.

Thus, when indigo, and other tranſparent vegetable paints, are united with oil, the air is thereby expelled from their interſtices; and the oil,

oil, which is admitted in its ſtead, from the nearneſs of its denſity, to that of the ambient powders, reflects no ſenſible light, ſo that the maſs, which conſiſts of ſuch uniformly denſe media, is black.

When ſmooth ſurfaces of dark-coloured marble, or ſlate, or of any other poliſhed coloured ſubſtances, are ſcratched, the air enters into the interſtices which are opened by this operation, and according to the exceſs of its rarity, over that of the maſſes whoſe particles it intercedes, it ſtrongly reflects a whiter, or lighter-coloured, hue. But, when by poliſhing the ſurface, or filling the pores with a denſer medium, the air is removed from them, the darker hue is reſtored.

From all the preceding experiments and obſervations, it appears that vegetable, animal, and mineral Coloured Matter is tranſparent; that it does not reflect colours, but exhibits them by tranſmiſſion only, that Opake Coloured Bodies conſiſt of tranſparent matter, which covers opake white particles, and tranſmits the light, which is reflected from them.

I ſhall, in the next place, examine the nature of Semipellucid Coloured Subſtances, which appear of one colour, when viewed by incident light, and of another, when viewed by tranſmitted light: and I ſhall endeavour to ſhew, from ſeveral experiments and obſervations, that, in theſe, as well as in Opake Coloured Bodies, no

no reflection is made by Coloured Matter, but by White, or Colourlefs, Particles only.

Semipellucid Subftances, which appear of one colour when viewed by incident light, and of another colour when viewed by tranfmitted light, confift of pellucid media, throughout which White, or Colourlefs, Opake Particles are diffufed.

The opake particles are difpofed at fuch diftances from each other, that fome of the incident rays of light are capable of paffing through the intervals which intercede them, and thus are tranfmitted through the femipellucid mafs.

Some forts of rays penetrate through fuch maffes, whilft other forts, which differ from them in their refrangibility, are reflected, by the White, or Colourlefs, Particles, and from thence are tranfmitted back through the pellucid part of the medium, which intervenes between the reflecting particles and the anterior furface of the mafs.

When pellucid colourlefs glafs is melted with arfenic, the arfenic is thereby divided into minute opake white particles, which are equably diffufed throughout the glafs. If only a fmall quantity of arfenic is ufed in this compound, the white particles are rarely diffeminated in it.

When glafs, thus combined with a fmall proportion of arfenic, is held between the window and the eye, it appears Yellow or Orange

 Coloured.

Coloured. When it is viewed by incident light, it exhibits a Blue Tinge. The yellow, or orange colour arifes from the tranfmiffion of the lefs refrangible rays, from whofe mixture that colour refults. The more refrangible rays are not tranfmitted through the glafs, but are reflected by the white particles, and pafs back through the Tranfparent Medium, which is between thofe particles and the anterior furface of the glafs.

I fhall here cite from Sir Ifaac Newton, a paffage, * from which it appears, that from the mixture of thofe rays, which are tranfmitted, a yellow, or orange colour muft be produced; and that thofe rays which were intercepted, and reflected, muft compofe a blue colour.

As the arfenical particles are equably diffufed throughout the glafs, with which they are combined,

* The letters R, and ϱ, refer to a figure in Sir Ifaac Newton's Optics (L. I. Part. II. Prop. VIII. Probl. III.) which reprefents the rays of light, caft on a white paper after they have been refracted through a prifm, and expreffes the compound colours which refult from the feveral mixtures of the differently refrangible rays. The following extracts relate to fuch mixtures of the rays, as produce blue, and orange colours.

"At R, where the violet-making, indigo-making, "blue-making, and one half of the green-making rays "are mixed, their colours muft compound a middle co-"lour between indigo and blue.

"At ϱ, the mixture of red, orange, yellow, and one half "of the green, muft compound a middle colour between "orange and yellow."

bined, confequently the fpaces, which intervene between thofe particles, are equal to each other: and the fpace alfo which intervenes between the furface of the glafs, and the arfenical particles which are neareft to the furface, is equal to the intervals which intercede the particles. And this may be farther fhewn, by breaking fuch maffes of glafs; for, the frefh furfaces of every fragment will appear fimilar to the original furface of the whole mafs.

From hence it is evident that, when a fmaller portion of arfenic is mixed with glafs, the intervals between the White Opake Particles will be larger, and therefore, the lefs refrangible rays will be more copioufly tranfmitted through them: and, in confequence of their lofs, the more refrangible rays which are intercepted, and reflected, by the particles of arfenic, will exhibit a bluer colour, and recede farther from whitenefs.

This obfervation is confirmed by experiment: for, although glafs, which contains a fmall proportion of arfenic, appears blue by incident, and orange coloured, by tranfmitted light; if a large proportion of arfenic be combined with the glafs, the compound, viewed by incident light, appears white, and no colour is tranfmitted through it, except it be made extremely thin. For, as the intervals between the particles, which are thus denfely difpofed throughout the glafs, do

not admit the paſſage of the leſs refrangible rays, they are not ſeparated from the more refrangible rays, but are conjointly intercepted and reflected, by the white particles, which are contiguous to the anterior ſurface, and therefore the maſs appears white.

When a bright light, ſuch as the ſun, or the flame of a candle, is viewed through a thick maſs of ſuch glaſs, ſo many of the more refrangible rays are intercepted, that the tranſmitted rays compound a Red Colour.

The glaſs, of which bottles are uſually made, affords another inſtance of a ſemipellucid ſubſtance, which exhibits a blue colour by incident, and a yellow or orange colour, by tranſmitted light.

This ſort of glaſs, when in its perfect ſtate, tranſmits a green colour, which it owes to the iron contained both in the vegetable aſhes, and in the ſea ſand, which enter into its compoſition.

The flux, by which the materials of this glaſs are fuſed, is ſo looſely connected with them, that it is diſengaged by expoſure to a red heat. In proportion as the glaſs is decompoſed, by the loſs of its flux, the earthy particles, which are no longer diſſolved, become Opake. If the glaſs be withdrawn from the fire, whilſt only a ſmall part of the flux is diſengaged, the maſs conſiſts of Tranſparent Glaſs, throughout which the opake earthy particles are diſſeminated.

If

If the glaſs be ſurrounded with white ſand, or other earthy ſubſtances, and expoſed to a greater heat, it entirely loſes its tranſparency, and texture, and aſſumes the appearance of porcelain or earthen ware, as M. Reaumur firſt obſerved. I have continued this proceſs ſo far, that the whole of the flux was diſengaged from the other materials of the glaſs.

After having expoſed, in a ſtrong, continued heat, the neck of a bottle, filled, and ſurrounded, with white ſand, I obſerved that all the flux had quitted the glaſs, and united with the ſand, which had been in contact with its external, and internal, ſurfaces. For the ſpace, which had contained the glaſs, was occupied by a looſe ſandy powder, and on each ſide of that ſpace, the white ſand was united into a firm, conſiſtent, maſs, which repreſented a mould, whoſe cavity was of the exact form, and ſize, of the neck of the bottle, from whoſe flux it received its ſhape, and conſiſtence.

When the glaſs, from the degree of heat, to which it has been expoſed, is reduced to ſuch a ſtate, that it conſiſts of a Tranſparent Medium, mixed with Opake White Particles, it exhibits a blue colour by incident light, and a yellow, or orange colour, by tranſmitted light. For, the more refrangible rays being intercepted and reflected by the white earthy particles, paſs back through the ſpace, which intervenes between

thofe particles and the anterior furface of the glafs; by which a blue colour is compounded. And the lefs refrangible rays, pervading the femipellucid medium, compound a yellow, or orange colour, as has been already explained, with refpect to the glafs combined with arfenic.

When a greater degree of heat is applied to the glafs, by which the opake earthy particles become more copious, the mafs appears almoft white. Becaufe, as in this denfe ftate of the opake particles, almoft all the differently refrangible rays are intercepted, and reflected, by them, a hue nearly approaching to whitenefs arifes from their mixture.

The quantity of ferruginous particles, in this mafs, is fo inconfiderable, and the colour produced by them is fo diluted by the numerous reflections from the white opake particles, that it becomes almoft imperceptible.

The atmofphere acts upon the rays of light, in the fame manner as the femipellucid media which have here been defcribed.

The blue colour of the fky is not produced by reflection from the atmofphere, confidered as an uniform extended mafs. For fuch a mafs would reflect the colour, from its furface. As reflections are made only at the furfaces of bodies, which differ, in denfity, from the media, which are contiguous to them; but the atmofphere does not reflect any coloured light from its furface.

Thus,

Thus, when the air contained in a chamber, or in a court or area, is viewed through a glaſs window, the ſurface of the atmoſphere, which is contiguous to the glaſs, reflects no colour, but is pellucid and colourleſs. Nor is any colour reflected by the ſurfaces of air, which are adjacent to water, cryſtal, or any other media, placed in contact with it.

The air contains a great variety of extraneous particles, which although they are almoſt, or entirely, imperceptible when ſeparate, yet, when viewed collectively, are capable of producing viſible reflections, by their united powers.

When a beam of light is admitted through a ſmall hole, into a dark chamber, innumerable motes are ſeen floating in the air, which is thus illuminated. Theſe minute bodies vividly reflect a white light around them, in every direction, ſo that they are diſtinctly ſeen from every part of the dark chamber. Such particles occupy all parts of the air which have been hitherto obſerved.

The atmoſphere abounds in volatile, and evaporable matters, which are diſengaged from natural bodies, by ſeveral operations, as fermentation, effervеſcence, putrefaction, the action of fire in volcanos, and various other means of decompoſition.

Many of the particles, which are ſeparated by ſuch proceſſes, differ conſiderably, in denſity,

from the air. And, as they are, for the moſt part, colourleſs, they reflect a white light, and therefore may be conſidered as white particles, diffuſed throughout the pellucid colourleſs air.

In this reſpect, the atmoſphere is ſimilar to the ſemipellucid medium, which is formed by diffuſing the white particles of arſenic, throughout pellucid colourleſs glaſs. In both theſe ſubſtances, whilſt the white, or colourleſs, particles are rarely diſſeminated through the tranſparent medium, the leſs refrangible rays are tranſmitted through the intervals which intercede the particles, and compoſe an orange, or red, colour: but, the more refrangible rays are intercepted, and reflected, by the particles, and the mixture of thoſe rays produces a blue colour.

In the air, as well as in the ſolid ſemipellucid media, when the white particles are more denſely arranged in the pellucid medium, the intervals which intercede them are diminiſhed, and the diſtance, between the ſurface of the pellucid medium, and the white particles, is alſo reduced.

In this ſtate of the atmoſphere, as the greateſt part of the yellow, orange, and red rays, are intercepted, and reflected, together with the more refrangible rays, they, by their union, exhibit a hue nearly approaching towards whiteneſs.

When the part of the atmoſphere, which is near the ſurface of the earth, is occupied by

groſs

grofs vapours, this mixture of air with aqueous, or other particles, is white: and, the anterior furface, as well as the interior parts, of the compounded medium, appears to be denfely ftored with white particles. Fogs, which confift of grofs vapours, feem chiefly to differ from clouds, in their depreffion, and contiguity to the furface of the earth.

When fuch vapours are elevated higher in the air, and form clouds, they reflect the white light of the fun, and thereby appear white, whenever its incident rays fall upon them intire and undivided.

As the reflective particles are not equally diffufed through every part of the pellucid air, of which the atmofphere principally confifts, it frequently happens, that large tracts of air are furnifhed with only fuch a portion of fubtile contents, as qualify them to reflect a blue colour; whilft others are fo denfely ftored with reflective particles, that they conftitute clouds.

The inferior parts of the atmofphere which are adjacent to the furface of the earth, conftantly abound in denfe exhalations, more than the higher regions.

Naturalifts have not hitherto obtained any confiderable infight into the nature, and origin, of the particles by which the tranfparency of the air is impaired, except as far as relates to aqueous

aqueous meteors. It is certain that ſome of the moſt extenſive, and permanent vapours, which have been obſerved in the atmoſphere, were not formed of aqueous or humid matter.

The miſt, which obſcured the air, during the ſummer of the year 1783, was remarkable for its extent. For, it involved almoſt all Europe, a part of Aſia, and of Africa, and perhaps reached much further: its altitude was ſo great, that the Alps were immerſed in it.

In moſt parts of Europe, the air, during the prevalence of this vapour, was unuſually dry. For, the hydrometer did not riſe to the point which denotes moiſture: ſalt cryſtallized in brine pits, before the ordinary period; and other proceſſes, which depend upon evaporation, were accelerated.

Several other curious obſervations, relative to this ſubject, are contained in an account written by M. Senebier of Geneva.*

When the air is repleniſhed with very denſe vapours, it tranſmits only the leſs refrangible rays, from whoſe mixture an orange, or red, colour is produced. Diſtant mountains covered with ſnow, clouds, or other white ſubſtances,

* The paper of this excellent philoſopher is inſerted in the Journal of the Abbé Rozier (Anno. 1784. May.) The ſame collection contains alſo inſtructive accounts of that ſubject by M. Toaldo, Profeſſor at Padua, M. Lamanon, and M. Marcorelle, Baron d'Eſcalle. (Jan. 1784.)

which

which are oppofed to the rays tranfmitted through the atmofphere, reflect their light, and thence affume their colours.

Sir Ifaac Newton attributed the various colours of the clouds, to the different magnitudes of the particles, whereby he conceived that they were qualified to reflect the differently refrangible rays. M. Melvill has more accurately remarked, that the colours of the clouds, at fun-rifing and fetting, do not depend on the fizes of their component particles, but arife merely from the colours of the rays tranfmitted through the tract of air which is contiguous to the horizon, and that they indifcriminately reflect the rays which are incident upon them.

This obfervation perfectly agrees with the phænomena. But the author of this remark does not feem to have formed any clear or precife conception of the conftitution of the atmofphere, and its action on the rays of light. He fuppofed, that the atmofphere is fimilar to Tranfparent Coloured Liquors.* But, it appears

* Phyfical Effays: Edinburgh. 1756. vol. II. p. 79. "To underftand why the fun's rays, by paffing through a "greater and greater quantity of air, change by degrees "from white to yellow, thence to orange, and laftly to "red, we have only to apply to the atmofphere, what Sir "Ifaac Newton fays (Book I. of his Optics, Part. II. Prop. "X.) concerning the colour of tranfparent liquors in "general."

appears from several parts of this inquiry, that Transparent Coloured Liquors do not reflect any colour, but appear black when viewed by incident light: therefore, the atmosphere, which exhibits colours by reflecting the incident light, does not, in its optical properties, resemble such liquors.

Mr. Melvill not only acquiesces in the general opinion, that colours are produced by the reflection of the several rays, from the Colouring Particles: but he extends his doctrine of the reflective power of those particles, so far as to attribute to them the action on light, whereby opake bodies are sooner heated by the sun-beams, than transparent ones. "As (according to him) "each *colorific particle* of an opake body, by the "reaction of the particles of light, must be "somewhat moved, when the light is *reflected* "backward and forward between the same "particles, it is manifest, that they likewise must "be driven backward and forward with a vibra-"tory motion." *

With respect to this hypothesis, I shall only observe, that, as the Colouring Particles of bodies do not reflect the rays, but appear black by incident light, even when contiguous to air: they cannot, according to any optical law, exercise a reflective power, when they are in contact with the internal parts of media, whose density

* Ib. p. 20.

greatly

greatly exceeds the denſity of air, and thereby approaches much nearer to that of the colouring matter itſelf.

When diſtant objects are ſeen, through a conſiderable tract of ſuch rare air as conſtitutes a blue ſky, thoſe objects aſſume the blue colour of the air. For they muſt be conſidered as reflective bodies, acting on the incident light, in the ſame manner as the reflective particles, which are diffuſed through the air. So that the reflected light paſſes back, from them, mixed with the blue rays, which are reflected by the minute extraneous particles of the atmoſphere.

If a denſer atmoſphere, or a longer tract of it, intervene between the objects and the eye, they become fainter and leſs diſtinct, and appear whiter; as the rays reflected from them are mixed with the whiter hue, which numerous particles communicate to the air.

By the interpoſition of a ſtill greater quantity of the reflective particles of the air, the objects diſappear. For the weak reflected light of diſtant objects, cannot, like the ſtrong light of luminous bodies, penetrate ſemipellucid ſubſtances, ſo as to tranſmit through them even the leſs refrangible rays.

Theſe, and all the phænomena of the atmoſphere, may be imitated, and explained, by artificial ſemipellucid ſubſtances, ſuch as have been here deſcribed.

Sir

Sir Ifaac Newton, and others, have fuppofed that the green colour of the fea is produced by the reflective power of the water. But, actual obfervations do not confirm, or agree with this opinion.

When fea water is admitted into a refervoir, which does not exceed a few inches in depth, the water appears pellucid and colourlefs. It is therefore manifeft, that no colour is reflected from its furface. Confequently, the water of the fea, confidered as an uniform extended mafs, does not reflect any colour.

Sea water abounds in heterogeneous particles. Magnefia is procurable from its analyfis: calcareous earth may be obtained in the fame manner, and manifefts itfelf in the numerous fhells, corals, and other calcareous concretions, which are formed in it. The ftrata, which compofe the bottom, and fhores, of the fea, alfo furnifh various faline, metallic, bituminous, and other matters. The animals, and vegetables, which it nourifhes, contribute to the production of extraneous particles. All thefe receive an addition from the rivers, which conftantly difcharge their contents into the fea.

Many of the earthy, and other, particles accede, in denfity, fo near to water, that, when they intercede that medium, their reflective power muft be very weak: but, as they do not entirely coincide with water, in denfity, they

muft

muſt be endued with a ſmall degree of reflective power. Therefore, although they may be inviſible, when ſeparately viewed, yet when the forces of a great number of ſuch minute bodies are united, their action on the rays of light becomes perceptible; ſome ſorts of rays being reflected by them, whilſt others are tranſmitted through their intervals, according to the quantity of reflective matter, which the rays arrive at, in the internal parts of the water.

The opacity of the ſea, cauſed by the numerous reflections from its internal parts is ſo conſiderable, that extenſive maſſes of it cannot be ſeen through: even although the obſtacle ariſing from the colourleſs light, reflected from its ſurface, be removed, by viewing the lower part of the water, through a dark tube immerſed under the ſurface, at the bottom of which a poliſhed glaſs plate is joined.

The nature and origin of the particles, which diminiſh the tranſparency of the water of the ſea, have not hitherto been examined, except as far as relates to the more obvious ſaline, and earthy, ſubſtances which are commonly obtained from its analyſis.

Yet, although the matter, of which theſe particles are formed, is not aſcertained, it is certain that they are endued with a ſomewhat greater reflective power, than thoſe which are ſuſpended

in

in the atmofphere, when in its rareft ftate. For the reflective particles, of the rareft fky, exhibit a blue colour, when viewed by incident light; but the reflective particles of the fea act upon a greater portion of the more refrangible rays; whereby they exhibit a green colour; and, (as Dr. Halley found from actual obfervation) tranfmit a rofe colour, which is red, inclining to violet, at fuch depths as only the lefs refrangible rays can penetrate. *

Sir Ifaac Newton obferves that thofe parts of thin plates of water, or air, which by tranfmitted light appear of a colour compounded of red and

* Newton. Opt. L. I. Part. II. Prop. X. Probl. V. "Of this kind, is an experiment lately related to me by "Mr. Halley, who in diving deep into the fea in a diving "veffel, found in a clear fun fhine day, that when he was "funk many fathoms deep into the water, the upper part "of his hand, on which the fun fhone directly through the "water, and through a fmall glafs window in the veffel, "appeared of a red colour, like a damafk rofe, and the "water below, and the under part of his hand, illuminated "by light reflected (*) from the water below looked "green." (*) All the green light, by which the under part of the hand was illuminated, was not reflected from the medium, which was beneath the veffel: for, a part of it was reflected from the ground, over which the veffel was placed. The light, thus reflected from the ground, was tinged green, by paffing through the fmall depth of water, which intervened between the ground, and the vacant fpace in the veffel, under the hand: whereby the rays, reflected, from the ground, were mixed with the green rays reflected from the internal parts of the fea water.

violet,

violet, exhibit a green colour by reflected light.* These he calls opposite colours, by which term he usually expresses those transmitted colours which are seen in the part of the medium, which is opposite to the reflected colours, and *vice versa.* †

All colours, transmitted by semipellucid substances, are opposite to those which the substances exhibit when viewed by incident light. And in proportion as Transparent Coloured Media grow opake, by the formation, or reception, of white, or colourless particles, the colours which they transmit recede farther and farther from the original colour, which the medium transmitted whilst it was transparent, until at last the mass grows so opake, that no rays are any longer transmitted.

I shall not enter upon any farther explanation of the manner in which the water of the sea acts upon the rays of light, as the observations which have been made respecting the air, and other semipellucid media, are likewise applicable to the optical appearances of the sea.

The semipellucid substances, which I have hitherto described, reflect the more refrangible, and

* Ib. Prop. V. Theor. IV. Exp. X. "If the red and "violet be intercepted, the remaining yellow, green and "blue, will compound a green."

† Ib. L. II. Part. I. Obs. IX. "By looking through "the two contiguous object glasses, I found that the inter- jacent

and tranſmit the leſs refrangible rays. Such media, for the moſt part, act upon the rays in a ſimilar manner.

The reflection, and tranſmiſſion, of the more or leſs refrangible rays, depend upon the powers of the reflective particles. The reflective, as well as the refractive, power of bodies being in a great meaſure proportionable to their ſpecific gravity.

Inſtances rarely occur either of natural, or factitious ſemipellucid ſubſtances, in which the reflective particles are of ſo great a ſpecific gravity, as qualifies them to reflect the leſs refrangible rays, ſuch as red, or orange; and, which at the ſame time are ſo minute, and ſo rarely diffuſed, that intervals are left between them, ſufficient to admit the paſſage of the rays.

The ſpecific gravity of gold is much greater than that of any other known ſubſtance, by which glaſs can be equably tinged. I therefore,

" jacent air exhibited rings of colours, as well by tranſ-
" mitting light, as by reflecting it.

" I found that white was oppoſite to black, red to blue, " yellow to violet, and green to a compound of red and " violet. That is, thoſe parts of the glaſs were black " when looked through, which when looked upon appeared " white, and on the contrary. And ſo thoſe which in one " caſe exhibited blue, did in the other caſe exhibit red, " and the like of the other colours."

judged

judged it expedient to examine in what manner the particles of that metal, combined with glaſs, would, under various circumſtances, act upon the differently refrangible rays.

For this purpoſe, I combined gold with pellucid colourleſs glaſs, after the manner of Kunckel, Caſſius, and others, by which a Tranſparent Coloured Glaſs was compoſed, which tranſmitted a bright red colour, but appeared black by incident light.

I expoſed ſeveral pieces of this red glaſs to the heat of burning coals; by which means, they loſt their tranſparency, and underwent an alteration in their texture. For, when the red glaſs is thus reheated, the particles of gold, uniting with ſome of the other ingredients of the glaſs, form Opake Moleculæ, which reflect all the rays, excepting the violet, and thereby appear by incident light, of a light brown hue.

If all the rays were equally reflected, the maſs would appear white, when viewed by incident light. But, the privation, of even a ſmall portion of them, impairs the whiteneſs, and reduces it to a brown hue, which is lighter, or more intenſe, as a greater or leſs quantity of the different rays are wanting in its compoſition.

The brown hue, reflected from the glaſs, which is here inſtanced, ariſes from the white light reflected from the Opake Particles, to which a ſmall proportion of all the rays, excepting the violet, is ſuperadded.

The violet rays are tranſmitted through the glaſs, and, therefore, it appears vividly tinged with a violet colour, when looked through.

In proportion as the tranſparency of this red glaſs is impaired, the tranſmitted colour recedes from red, till it becomes violet: according to the law which all Tranſparent Bodies obſerve, when Opake Particles are introduced into, or formed in them, ſo as to render them ſemi-pellucid.

This experiment manifeſts the ſtrong reflective power, with which the particles of gold are endued, according to their ſpecific gravity.

In this kind of glaſs, and in all other Semi-pellucid, as well as Opake, Coloured Subſtances, colours are reflected from White, or Colourleſs Particles only, and are tranſmitted through the Tranſparent Parts of the Media.

It is not neceſſary to extend this ſubject, by a deſcription of Semipellucid Liquors, as they act according to the ſame laws, and afford the ſame appearances, as the ſolid media, which have been already inſtanced.

In the preceding experiments, I have preferred the uſe of ſemipellucid glaſſes, becauſe they are not apt to be decompoſed, or ſuffer any variation in their texture; and therefore are diſpoſed, con-ſtantly, and equably, to exhibit the ſame colours.

The coloured light, which is tranſmitted through Semipellucid Subſtances, paſſes through the in-

tervals

tervals which intercede the Opake Particles diffufed through them. For, when the Opake Particles are fo denfely arranged, that they interfect, and cover, the interftices which lie between them, the paffage of the rays is obftructed, and none of them are tranfmitted: but, the mafs ceafes to be femipellucid, and becomes opake.

The fame caufe of obftruction to the paffage of the rays takes place in Tranfparent Coloured Bodies, when the Colouring Particles are denfely arranged: fo that the light is intercepted and abforbed, by the colouring matter, and the mafs, confequently, appears black, in whatfoever direction it is viewed.

From feveral experiments, and obfervations, which I have made, in the courfe of this inquiry, it appears, that the rays of light are tranfmitted through Tranfparent Coloured Subftances by means of a power, with which they are endued; and, that thofe Media tranfmit Coloured Light with the greateft ftrength, which have the greateft refractive power.

The ftrong refractive, and reflective, power of inflammable bodies has been obferved by Sir Ifaac Newton. But, the power, of fuch bodies, to tranfmit the rays otherwife than by refracting them, has not, I believe, hitherto been noticed.

The following experiments prove, that the Tranfmiffive Power, of Inflammable Coloured Media is much ftronger, than the Tranfmiffive

Power of Coloured Media, which do not abound in phlogiftic matter.

To a dilute folution of green vitriol in diftilled water, I added a fmall quantity of an aqueous infufion of galls. The liquor, compofed of thefe ingredients, tranfmitted a blue colour, which, although perfectly diftinct, and unmixed with any other hue, was not vivid, but appeared as a coloured fubftance not acting upon a fufficient quantity of the rays of its own colour.

I made a tincture, by digefting green vitriol in fpirit of wine, and, to a portion of this tincture, diluted with a farther addition of fpirit of wine, I applied a fmall quantity of a ftrong fpirituous tincture of galls. This liquor, thus prepared, tranfmitted a blue colour, greatly excelling in beauty and brightnefs.

The ftrength, of the tranfmiffive power of inflammable media, is manifeft from a comparative view of thefe proceffes, and others which have been already inftanced.

Sir Ifaac Newton attributed the colours of natural bodies, to the feveral fizes and denfities of their particles, by which, according to him, they *reflect* feveral forts of rays, and thereby appear of feveral colours.

It has been fhewn, throughout this inquiry, that the Colouring Particles are not endued with a reflective power, but produce their feveral colours by tranfmitting the feveral forts of rays.

The

The experiments, made with thin plates of glaſs, water, and air, from which Sir Iſaac Newton inferred, that the ſeveral colours of natural bodies ariſe from the ſeveral ſizes and denſities of the particles, were executed with ſo much ſkill and preciſion, and have been ſo often ſucceſsfully repeated, by later inquirers, that they are firmly eſtabliſhed.

But, the doctrine of a reflective power exiſting in the Colouring Particles, does not appear to be deducible from thoſe experiments, nor is it conformable to any ſubſequent obſervations.

Sir Iſaac Newton obſerved, that thick plates of glaſs yield * rings of colours, in the ſame manner as the thin plates, from whoſe appearances he deduced this explanation of the colours of natural bodies.

The Duke de Chaulnes has proved, that none of the colours, exhibited by ſuch thick plates, are reflected by the anterior ſurface of the glaſs; but that the rays, after having paſſed through the firſt ſurface, to the farther ſurface, are thence reflected back †.

May it not from hence be inferred, that, ſince the action of thick plates, in exhibiting colours, is analogous to that of thin plates, the colours, even in theſe, are not produced by reflection from the anterior ſurface, but by a remoter reflection,

* Newton. Opt. L. II. Part. IV.

† Acad. Paris. Ann. 1755. p. 136.

and by a ſubſequent tranſmiſſion through the pellucid glaſs.

From all the experiments which I have here adduced, it uniformly appears, that no Coloured Light is reflected from the anterior ſurfaces of Opake, Semipellucid, or Tranſparent Coloured Bodies. For, in theſe, the light is reflected by the ſuperficies which intercedes the tranſparent part of the medium, and the ſubſtance which is behind it: and the light, thus reflected, is tranſmitted back, through the tranſparent part of the medium, which intervenes between the reflective ſurface, and the anterior ſurface.

In theſe reſpects, the Coloured Media, which have been examined throughout the courſe of this inquiry, agree with the plates of glaſs obſerved by the Duke de Chaulnes.

If the experiments, which have been made with thin Tranſparent Colourleſs Subſtances, and thoſe which have been performed with Coloured Media, be jointly conſidered, it will appear that the effects, which Sir Iſaac Newton has attributed to Reflected Light, ſhould have been applied to Tranſmitted Light. And the obſervation of this great philoſopher, relative to the connection between the colours of natural bodies, and the ſize and denſity of their particles, if thus modified, will coincide with his own experiments, and all the others which have been made ſubſequent to them.

In a former work, I have ſhewn by a ſeries of experiments, that the changes of colour, which Permanently Coloured Subſtances undergo, are made in a regular order, accordingly as the ſizes of their colouring particles are diminiſhed, or augmented.

I have here adduced ſome examples of the influence of denſity and of phlogiſton, on the colours of the bodies.

Beſides theſe means, by which the colours of ſome ſubſtances are affected, I have frequently obſerved that there is another cauſe, by which changes are produced in Tranſparent Coloured Media, not only in the degree, but alſo in the ſpecies of the colour.

Theſe changes ariſe from the greater, or leſs obſtruction which the rays meet with, in their paſſage through the interſtices which intercede the Colouring Particles; according to the thickneſſes of the media, and the quantity of colouring matter diffuſed through them.

Tranſparent Coloured Media act upon the rays of light, more ſimply and uniformly, than Semipellucid Subſtances: becauſe, in theſe a greater variety of phænomena reſult from the different forces of the Opake Particles: by which ſome of the rays are reflected, whilſt others are tranſmitted.

Although all Tranſparent Coloured Media tranſmit a leſs quantity of the incident rays,

in

in proportion as the paſſage through their interſtices is obſtructed; ſome of thoſe media, during the decreaſe of their tranſmitted light, do not vary the ſpecies of their colour: but, in other Tranſparent Coloured Media, the tranſmitted colours are changed, by the reſiſtance to which the rays are oppoſed, during their paſſage through the interſtices.

The changes, which are thus effected in Tranſparent Coloured Media, generally proceed in one and the ſame order. So that, in proportion as the paſſage of the more refrangible rays, through ſuch ſubſtances, is obſtructed, the leſs refrangible rays, by their greater momentum, penetrate the medium and are tranſmitted through it.

From the mixture of the leſs refrangible rays, which are thus tranſmitted, the maſs exhibits either a red, or ſome colour inclining to red, in proportion as a greater or leſs quantity of the more refrangible rays are intercepted.

It is probable, however, that ſome inſtances may be found, of media whoſe changes of colour do not coincide with this general rule. Eſpecially, if ſuch media owe their colours to phlogiſtic matter, or to particles which differ greatly in denſity, from the pellucid part of the ſubſtances through which they are diffuſed.

I have not met with any obſervations, relative to the changes of colour, ariſing from the

cauſe

caufe which is here confidered, excepting fuch as relate to yellow liquors, which are apt to tranfmit orange, and red colours, in proportion as the rays are tranfmitted through greater thickneffes of fuch media.

Sir Ifaac Newton, in the following paffage, has attributed, to red liquors, the property of tranfmitting thefe colours, according to the different thickneffes of the liquors. "A red liquor "in a conical glafs held between the light and "the eye, looks of a pale and dilute yellow at "the bottom where it is thin, and a little higher "where it is thicker grows orange, and where "it is ftill thicker becomes red, and where it is "the thickeft the red is deepeft and darkeft." *

The liquor, which was the fubject of this obfervation, was, probably, an aqueous or fpirituous infufion of fome of the woods which are ufed in dying red. For, thefe tranfmit a yellow, orange, or red colour, according to their thickneffes, or tenuity.

But, red liquors do not tranfmit orange, or yellow, colours, even when fpread thin. Several red liquors are enumerated in the table p. 166, fuch as the nitrous folution of cobalt, the red infufions of flowers, the red juices of fruits, and berries; and feveral others. When thefe liquors are difpofed in thicker, or thinner, maffes, they

* Newton. Opt. L. I. Part. II. Prop. X. Probl. V.

do

do not vary the ſpecies of their colour, but only tranſmit a diluter, or more intenſe red.

Nor do red glaſſes appear yellow, or orange, when divided into the thinneſt plates.

Theſe Tranſparent Red Media, from the interception of the tranſmitted rays, ſuffer no other change, except the diminution, or loſs, of their colour, whereby they aſſume a darker hue, or become black.

As the changes of colour, thus effected in yellow liquors, have been already obſerved, I ſhall not mention any experiments relative to them, but ſhall advert to other media, whoſe phænomena have not, I believe, been hitherto noticed.

I digeſted, in ſpirit of wine, a ſufficient quantity of ſap green, which is an expreſſed vegetable juice, inſpiſſated, and dried. When the ſpirit of wine was ſaturated with this colouring ſubſtance, it was filtered through paper, and afterwards poured into a ſmall flint-glaſs bottle which was of the form of a wedge, or triangular priſm.

That portion of the coloured liquor, which was contained in the angular part of the bottle, and which, conſequently was the thinneſt, tranſmitted a vivid green colour; that portion, which was in the wideſt part of the bottle, tranſmitted a bright red colour; the intermediate portion, which was between the green and the red, tranſmitted a yellow colour: but the yellow

was

was much inferior to the two other colours, both in quantity and brightneſs. The liquor, when viewed by incident light, appeared black.

Sap green infuſed in diſtilled water, and viewed in a ſimilar bottle, tranſmitted the ſame colours. But, the green was not ſo copious, or ſo vivid, as in the ſpirituous tincture; and the proportion of the yellow was likewiſe diminiſhed.

Theſe experiments afford a farther inſtance of the ſuperior tranſmiſſive power of inflammable media; ſince the more refrangible rays are more copiouſly, and more vividly, tranſmitted by the ſpirituous tincture, than by the aqueous infuſion.

By infuſing graſs, and other green leaves, in ſpirit of wine, I obtained a tincture, conſiſting of the ſpirit of wine ſaturated with the colouring matter of the leaves. This was examined in the ſame manner as the preceding liquors: it tranſmitted a bright green, where it was thinneſt; and a vivid red, where it was thickeſt: but, the intermediate yellow was ſcarcely perceptible. This, as well as the two former liquors, appeared black, when viewed by incident light.

I infuſed litmus in diſtilled water, and having thus procured a coloured infuſion, I filtered it, and examined it, in the ſame manner as the liquors, which have been already deſcribed. This infuſion tranſmitted an azure blue colour, where it was thinneſt; and a bright red, where it was thickeſt. The intermediate colour was purple. This liquor

quor alſo appeared black, when viewed by incident light.

When theſe liquors are ſufficiently diluted, each of them tranſmit the more refrangible rays, even when they are contained in the wideſt part of the priſmatic bottles. For, the greater thickneſſes of diluter coloured liquors, contain no more coloured particles, than thinner maſſes, which are more intenſely coloured.

Theſe phænomena ſeem to indicate, that the power, by which the ſeveral rays of light are tranſmitted through Coloured Media, is inherent in the Colouring Particles themſelves, and therefore, is not confined to the ſurfaces of ſuch media. For, if the tranſmiſſive force was exerted at the ſurfaces only, thinner plates of Coloured Subſtances would act upon the rays, as powerfully as thicker maſſes. But, it appears, from experiment, that, in proportion as the rays paſs through different thickneſſes of coloured media, they exhibit colours, differing, not only in degree, but, frequently, in ſpecies alſo.

The ſun's light, by which bodies are illuminated, conſiſts of all the rays, by which a white light is compounded. Theſe rays, in their entire and undivided ſtate, are incident upon the Opake Particles of Semipellucid Subſtances; and, upon the Colouring Particles of Tranſparent Coloured Subſtances, whenever thoſe media are expoſed to the light.

When

When the rays accede to the opake particles of ſemipellucid ſubſtances, ſome ſorts of them are reflected back, from the anterior ſurface of thoſe particles: the other ſorts of rays, which are not reflected back, are diverted from the direction which is oppoſite to the anterior ſurface of the opake particles, and, paſſing through the intervals, between the particles, are tranſmitted through the maſs.

When the rays are incident upon the particles of Tranſparent Coloured Bodies, none of them are reflected back, becauſe the colouring particles are not endued with any reflective power. But, ſome of the rays are either ſtopt at the anterior ſurfaces of the particles, or are diverted into ſuch directions, as render them incapable of paſſing towards the farther ſide of the maſs, and, conſequently ſuch rays cannot be tranſmitted. The rays, which are not thus intercepted, or diſperſed, are tranſmitted, in the ſame manner as thoſe which paſs through ſemipellucid media.

Thus it is evident, that the coloured rays, which are tranſmitted through ſemipellucid ſubſtances, are *inflected* by the Opake Particles: and thoſe which are Tranſmitted through Tranſparent Coloured Subſtances, are *inflected* by the colouring particles.

I have already ſhewn, that thoſe media tranſmit coloured light with the greateſt ſtrength, which have the greateſt refractive power. From the preceding

preceding obſervations, it appears, that the particles of coloured media inflect the ſeveral ſorts of rays, according to the ſeveral ſizes, and denſities, of the particles; and alſo, in proportion to the inflammability, of the media which owe their colour to them: and it is manifeſt, that the tranſmiſſion of coloured rays depends upon their inflection.

All theſe obſervations are conformable to Sir Iſaac Newton's doctrine, that the rays of light are reflected, refracted, and inflected, by one and the ſame principle, acting variouſly in various circumſtances.

I have hitherto inveſtigated, and explained, the powers and operations, by which the rays of light are tranſmitted through coloured media; and, have ſhewn that, in Opake coloured Bodies, they are reflected by the Opake particles, which are conſtituent parts of ſuch bodies, and, that the light, thus reflected, paſſes back through the Tranſparent Colouring Matter, with which the opake particles are covered.

It appears, both from the analyſis of Opake Coloured Bodies, and from ſeveral other experiments and obſervations, that the matter, by which they reflect the light, conſiſts of white particles.

The ſolid parts of animals, and vegetables, are principally compoſed of calcareous earth, which is a perfectly white ſubſtance. This earth alſo abounds in the mineral kingdom, as well as the ſiliceous, and argillaceous, earths, and magneſia, which

which alſo are perfectly white, when pure, and diveſted of adventitious matters.

All theſe earths conſtitute Tranſparent Colourleſs Media, when they are vitrified, together with proper fluxes; or when they are diſſolved in colourleſs menſtrua. And the ſaline maſſes, which are obtainable from their ſolutions, are tranſparent and colourleſs, while they retain the water which is eſſential to their cryſtallization, and are not flawed, or reduced to powder.

But when, by ſuch means, the interſtices of thoſe maſſes are evacuated, or opened, they are rendered white and opake, by the admiſſion of air, or of a rarer medium.

The earthy particles, which form the ſolid parts of bodies, generally exceed, in denſity, the other conſtituent particles, which they intercede. For, in the compoſition of bodies, earths are, for the moſt part, combined with aqueous, aërial, ſaline, or inflammable matters; all of which are greatly inferior to earths, in their ſpecific denſity. And, therefore, the ſurfaces of the earthy particles, which are contiguous to ſuch media, muſt reflect the rays of light, with a force which is proportionate to their exceſs of denſity.

The reflective power of bodies does not depend merely upon their exceſs of denſity, but upon their difference of denſity, with reſpect to the ambient media. Therefore, Tranſparent Colourleſs Particles, whoſe denſity is greatly inferior to that of the media which they intercede, alſo powerfully

reflect all the ſorts of rays, and thereby become white.

Of this kind are the air, or other rare fluids, which occupy the interſtices of liquors; of tranſparent ſolid bodies, flawed, or reduced to powder, or otherwiſe minutely divided; of porous ſolid ſubſtances; of calces of metals; and in general of all denſer media, into whoſe interſtices ſuch rarer particles are admitted.

Theſe obſervations are grounded upon Sir Iſaac Newton's doctrine, relative to the tranſparency, and opacity of Colourleſs Subſtances. And from thence it may be deduced, that white opake bodies are conſtituted by the union or contiguity of two, or more, Tranſparent Colourleſs Media, differing conſiderably from each other, in their reflective powers.

Such white ſubſtances are inſtanced in froth, emulſions, or other imperfect combinations of pellucid liquors, milk, ſnow, ſalts calcined or pulverized, glaſs, or cryſtal, reduced to powder, white earths, paper, linen, and even thoſe metals, which are called white by the mineralogiſts and chymiſts. For thoſe metals do not appear white, unleſs their ſurfaces be rough. Becauſe, the ſurfaces of poliſhed metals do not afford interſtices, into which air, or other rare fluids capable of reflecting light, can be admitted.

But, when interſtices are opened on the ſurfaces of metals, by roughening them, the air occupies thoſe interſtices, and its moleculæ, according to the

the great difference of their denſity, with reſpect to that of the metal, vividly reflect a white light.

The rough ſurfaces of metals conſiſt of minute irregular prominences, and cavities, from which the rays are reflected, in different directions, whereby they are blended and intermixed, and, by their mixture, conſtitute whiteneſs.

But, the poliſhed ſurfaces of metallic mirrours equably, and regularly, reflect the ſeveral incident rays, according to their ſeveral angles of incidence: ſo that the reflected rays do not interefere with each other, but remain ſeparate and unmixed, and therefore diſtinctly exhibit their ſeveral colours.

From hence it is evident, that white ſurfaces cannot act upon the light, as mirrours: becauſe all the rays, which are reflected from them, are promiſcuouſly, and diſorderly blended.

Nor can the ſurfaces of mirrours appear white, except when white objects are caſually oppoſed to them: becauſe the rays which fall upon them from coloured objects, are reflected ſeparately, and diſtinctly, whereby colours are exhibited.

In forming ornamental works of ſilver, artiſts ſometimes avail themſelves of the contraſt, between the reſplendent whiteneſs of the unpoliſhed parts of the metal, and the regular reflections which are diſplayed by its poliſhed parts.

White metals are peculiarly adapted to the formation of mirrours, as their ſurfaces are capable of being poliſhed, by which they are qualified

equably, and regularly, to reflect the incident rays; as their reflective power is proportionate to their specific density, which is very great; and as they are disposed indiscriminately to reflect all the differently refrangible rays.

Mercury, silver, lead, and tin, are pellucid and colourless, when dissolved in their proper menstrua. In the solutions of other metals, some colouring particles are mixed with the colourless particles. The opacity, and the vivid lustre of the entire metals, which consist of those pellucid particles, united with phlogiston, arise from the powerful reflection of the surfaces, which intercede the metals and the air.

Metals do not owe their shining appearance to their metallic particles, but to their phlogiston. For, calcination, which disengages the inflammable principle from metals, deprives them also of their lustre.

The reflective power, of the inflammable principle, is so great, that it imparts, to various pellucid colourless substances, a shining appearance, perfectly resembling the lustre, and hue, of metals.

Plumbago, which has a metallic appearance, and lustre, consists of two substances, which, when separate, are not only pellucid, and colourless, but absolutely invisible. For its sole constituent parts are phlogiston, and fixed air. *

* D. Scheele, in Act Stockh. 1778.

Many

Many marcaſites, which ſcarcely yield to any of the metals, in luſtre, do not contain any metallic particles, but conſiſt principally of ſulphur, which itſelf is compoſed of phlogiſton, and vitriolic acid.

Nor is the luſtre, and metallic appearance, confined to ſubſtances which abound in phlogiſton: for, it is exhibited by the ſurfaces of ſeveral Pellucid Colourleſs Media, which vividly reflect the light; from the difference between their denſity, and that of the ambient media; from their gloſſy ſmoothneſs or poliſh; or from various other cauſes.

Mr. Melvill has clearly explained the ſilver-like appearance, which drops of water exhibit, when they lie on the leaves of colewort, and ſome other vegetables. He obſerved, that the luſtre of thoſe drops, is produced by a copious reflection of light, from the flattened part of their ſurfaces, contiguous to the plant; that the drops, when they have that appearance, do not touch the plant, but are kept at ſome diſtance from it, by the force of a repulſive power, or medium, which occupies the intervals between the drops and the leaves: that, as the ſurfaces of the leaves are conſiderably rough and unequal, the under ſurfaces of the drops become rough likewiſe, and ſo by reflecting the light copiouſly, in different directions, aſſume the reſplendent whiteneſs of unpoliſhed ſilver. *

* Phyſical Eſſays: Edinburgh. 1756. vol. II. p. 25.

When Pellucid Colourlefs Glafs is broken, it fometimes happens that, the frefh furface of the fragment is very fmooth and gloffy. If fuch a fragment of glafs be fo placed, that the frefh broken part may be feen at the farther furface, that part cannot be diftinguifhed by the fight, from a fimilar portion of glafs covered with quickfilver.

This effect is produced, by the copious reflection of light from the broken part, which greatly exceeds in fmoothnefs, the original furface of the glafs. For, melted glafs, from its tenacious confiftence, affumes, whilft it cools, a furface lefs gloffy than thofe which are expofed, by breaking it. Many other like inftances may be adduced.

Thefe phænomena afford much infight into the nature, and caufe, of opacity. As they clearly fhew, that even the rareft Tranfparent Colourlefs Subftances, when their furfaces are adjacent to media greatly differing from them in refractive power, may thereby acquire a perfect opacity, and may affume a refplendency, and hue, fo fimilar to that of white metals, that the rarer pellucid fubftances cannot, by the fight, be diftinguifhed from the denfe opake metals. And, this fimilarity to the furfaces of metals occurs, in the rare pellucid fubftances, not only when, from the roughnefs of their furfaces, they refemble unpolifhed metals in their vivid whitenefs; but alfo when, from their fmoothnefs,

ſmoothneſs, they reſemble the poliſhed ſurfaces of metals.

Metals ſeem to conſiſt entirely of Tranſparent Matter, and to owe their apparent opacity, and luſtre, ſolely to the copious reflection of light from their ſurfaces. The analogy between the metals and Tranſparent Media, as far as reſpects their optical properties, will appear from the following conſiderations.

(1) All metals, diſſolved in their proper menſtrua, are tranſparent. (2) By the union of two or more tranſparent media, ſubſtances are conſtituted, which are ſimilar to metals, in their opacity and luſtre, as has been inſtanced in plumbago, and marcaſites. (3) The Tranſparent Subſtances of metals, as well as of thoſe minerals, by their union with Phlogiſton, acquire their ſtrong reflective powers, from which their luſtre and opacity ariſe. (4) The ſurfaces of pellucid media, ſuch as glaſs, or water, aſſume a metallic appearance, when by their ſmoothneſs, their difference of denſity with reſpect to the contiguous media, or any other cauſe, they are diſpoſed copiouſly to reflect the light.

From all theſe conſiderations, it is evident, that opake ſubſtances are conſtituted by the union, or contiguity, of Tranſparent Colourleſs Media, differing from each other in their reflective powers; and, that, when the common ſurface, which intercedes ſuch media, is plane, equal, and ſmooth, it

reflects the incident rays equally, and regularly, as a mirrour: but, when the surface is rough, and unequal, or divided into minute particles, it reflects the incident rays irregularly, and promiscuously, in different directions, and consequently appears white.

As the surfaces of pellucid colourless media are disposed indiscriminately to reflect all the rays of light; so white opake substances, which are compounded of pellucid colourless media, retain the same disposition, which is indifferent to all the sorts of rays.

It has been already shewn, throughout the course of this inquiry, that coloured matter does not reflect any light; but, that reflective media act indiscriminately on all the different rays. It does not appear from the optical phænomena, which have hitherto been observed, that nature affords any kind of matter endued with a power of reflecting one sort of rays, more copiously than the other sorts. Consequently, no reflective substances are capable of separating the differently refrangible rays, and thereby producing colours.

There are several experiments, and observations, in Sir Isaac Newton's Optics, from which it might have been inferred, that coloured light is not reflected from coloured matter, but from white or colourless matter only.

Although that great philosopher supposes, that all coloured bodies reflect the rays of their own colours,

colours, more copiously than the rest, yet he observes, that " they do not reflect the light of their " own colours so copiously as white bodies do. " If red lead, for instance, and a white paper, be " placed in the red light of the coloured spectrum " made in a dark chamber by the refraction of a " prism, the paper will appear more lucid than " the red lead, and therefore reflects the red-" making rays more copiously than red lead " doth." *

If it be supposed, that the red particles of the minium reflect the red rays, more strongly than the rest, what reason can be assigned, why minium should not exhibit the red rays as vividly as white paper, which acts indifferently on all the rays.

But, if it be considered that, in opake coloured bodies, the rays, which are reflected from white reflective matter, pass back through the Transparent Coloured Media, with which the reflective matter is covered, it will evidently appear, why the coloured light reflected from white paper, is more copious and bright, than that which is exhibited by red lead.

A considerable part of the incident light is lost, in passing through Transparent Coloured Media. Therefore, the light reflected immediately from the white paper, must be more copious and lucid, than that which has undergone a diminution, in its passage to, and from, the reflective particles

* Newton. Opt. L. I. Part. II. Prop. V. Exp. 15.

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of the Opake Coloured Body, through the Tranf-parent Coloured Medium.

When a fmall portion of colouring matter is mixed with a colourlefs medium, the mafs appears tinged with colour; but, when a great quantity of colouring matter is added, the mafs exhibits no colour, but appears black. Therefore, to attribute to colouring matter a reflective power, is to advance an inexplicable and contradictory propofition: for, it is afferting, that, in proportion as more reflective colouring matter is oppofed to the incident light, lefs colour is reflected; and that, when the quantity of colouring matter is very great, no colour at all is reflected, but blacknefs is thereby produced.

From thefe arguments, it might have been fhewn, that the reflective power does not exift in colouring matter, but in Opake White Subftances only. Neverthelefs, in this difquifition, I have not entirely relied on arguments drawn from a few, known and obvious, appearances, but have endeavoured, by numerous experiments, to afcertain the caufe of the colours of natural, as well as artificial bodies, and the manner in which they are produced.

M. Euler obferved, * that the colours of bodies are not produced by reflection. He fuppofes that the coloured rays are emitted by the colorific particles. This hypothefis, however, is not agreeable to experiment. For, as the colouring matter

* Acad. Berlin. Ann. 1752. p. 262.

acts

acts upon light, by tranſmiſſion only, it is evident that bodies do not appear coloured either by reflecting, or emitting the rays.

I have not attended to any other hypotheſis, which are unſupported by experiments.

Sir Iſaac Newton, and, I believe, all later philoſophers, except M. Euler, have attributed to colouring matter a reflective power. And the artiſts, whoſe works depend upon the preparation, and uſe of colouring materials, ſeem, in general, to have adopted the ſame theory.

As an inſtance of this agreement, I have cited, from M. Hellot, one of the moſt ſkilful and intelligent authors, who have treated of the Art of Dying, a paſſage which comprizes his opinion reſpecting the action of the tinging particles on the rays of light. *

All the other writers, on the ſame ſubject, appear to agree in that eſtabliſhed opinion: but,

* "Hellot. Art de la Teinture des Laines. 1772, p. 117. Nous ne connoiſſons, juſqu' a préſent, que deux plantes, qui donnent le bleu, après leur préparation; l'une eſt l'Iſatis ou Glaſtum, qu'on nomme Paſtel en Languedoc, et Vouede en Normandie; leur préparation conſiſte dans la fermentation continuée preſque juſqu' à la putréfaction de toutes les parties de la plante, la racine exceptée; par conſéquent, dans un développement de tous leurs principes, dans une nouvelle combinaiſon et arrangement de ces mêmes principes, d'où il réſulte un aſſemblage de particules infiniment déliées, qui, appliquées ſur un ſujet quelconque, y *réfléchiſſent* la lumiere bien différemment de ce qu' elles feroient, ſi ces mêmes particules étoient encore jointes à celles que la fermentation en a ſéparées."

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they ſeem rather to have yielded to the authority of Sir Iſaac Newton, and other theoriſts, than to have appealed to the operations of their own art, from which the real cauſe and origin of colours is obviouſly deducible.

The Art of Dying conſiſts, principally, in covering white ſubſtances, from which light is ſtrongly reflected, with Tranſparent Coloured Media, which, accordingly to their ſeveral colours, tranſmit, more or leſs copiouſly, the ſeveral rays reflected from the white ſubſtances.

The Tranſparent Coloured Media themſelves reflect no light: and it is evident that, if they yielded their colours by reflecting, inſtead of tranſmitting, the rays, the whiteneſs, or colour of the ground on which they are applied, would not anywiſe alter, or affect, the colours which they exhibit.

Such an erroneous conception of the principles of the art, cannot fail greatly to obſtruct its progreſs, and improvement. All colouring matter is black, when viewed by incident light, and all ſubſtances incline to blackneſs, in proportion as they are copiouſly ſtored with tinging particles.

The Artiſt therefore, who confines his inquiries to ſubſtances which reflect the light, cannot be ſucceſsful in his endeavours to diſcover new dying materials: and, if he is led, by experience, to extend his reſearches to other ſubſtances, his practice contradicts his principles; by which his views

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are obſcured, and bounded within the narrow limits of accidental obſervation.

The knowledge of the optical properties of colouring matters, is alſo eſſentially requiſite to their due preparation and uſe. As the practice of dying, in its preſent ſtate, is not regulated by any ſcientific rules, it is ſeldom improved by the introduction of new proceſſes: and the methods of varying the uſes of the materials, which are already known, are rarely aſcertained without repeated trials.

All the operations of the art, excepting only a few which have ariſen from accidental diſcoveries, owe their origin to remote ages.

We learn from the teſtimony of the ſacred writers, as well as of the later hiſtorians, that the Indians, Egyptians, Phœnicians, and other ancient nations, excelled in the art of dying. From the accounts, which are delivered down to us, of the colouring materials which they uſed, and of the clothes which were dyed with them, we find evident proofs, that they were acquainted with the principles, as well as the practice, of the art.

The ancients did not attribute a reflective power to the colouring matter; but held, that the dyed clothes reflected leſs light, in proportion as they were more copiouſly ſtored with tinging particles. They eſtimated the richneſs and intenſeneſs of the dye, by its approach to blackneſs.

Pliny, who has recorded many curious circumſtances relative to the arts, deſcribes indigo, when undiluted,

undiluted, as a *black* subſtance. * The ſame author informs us, that the ſpecies of Tyrian dye, which was moſt eſteemed, was of a roſe colour *inclining to black*; † and that the red was inferior to that which was blacker. ‡ He accurately diſtinguiſhes the bright red colour, which is tranſmitted through the dyed clothes, from the dark hue, which they exhibit when viewed by incident light. ‖

The inattention of later philoſophers, and artiſts, to the reflective, and tranſmiſſive, qualities of the conſtituent parts of Coloured Subſtances, has, doubtleſs, impeded the progreſs and improvement

* Plinii, L. XXXV. C. 6. Ab hoc maxima autoritas Indico. Ex India venit harundinum ſpumæ adhæreſcente limo. Cum teritur *nigrum*. At in diluendo mixturam purpuræ cæruleique mirabilem reddit.

† Ib. L. IX. C. 36. Purpuræ florem illum tingendis veſtibus expetitum, in mediis habent faucibus. Liquoris hic eſt minimi in candida vena, unde pretioſus ille bibitur *nigrantis* roſæ colore ſublucens.

‡ Ib. L. IX. C. 38. Rubens color *nigrante* deterior.

‖ Ib. L. IX. C. 38. Laus ei ſumma, color ſanguinis concreti, *nigricans aſpectu*, idemque *ſuſpectu refulgens*.

It appears from the following paſſage, cited from Macrobius, that the dealers in dyed clothes were accuſtomed to conſider the colours, which they yielded by tranſmiſſion, as well as thoſe which they afforded, when viewed by incident light. " Cum de Tyriæ purpuræ, quam emi juſſerat, obſcuritate quereretur (Auguſtus) dicente venditore, erige altius et ſuſpice, his ſalibus uſus eſt: Quid? ergo ut me populus Romanus dicat bene cultum, in ſolario ambulaturus ſum?" Macrob. Lib. II. Saturn.

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of the ſcience of optics, and of the arts which are dependent upon it. This experimental reſearch was undertaken, for the purpoſe of examining the optical qualities of ſuch ſubſtances.

During the courſe of my inquiry, I have obſerved, that the tranſition from phyſical experiments, to practical operations of dying, is eaſy and obvious. For, the experiments, which I have made, with a view of inveſtigating the origin and cauſe of colours, have guided me to the diſcovery of ſeveral bright and permanent dyes, in the execution of which I have, principally, uſed cheap and common ingredients, that have not before been applied to ſuch purpoſes.

I do not doubt, that a clear, and comprehenſive, view of the principles of the art will open, to the artiſts who practiſe it, a fertile ſource, from which, with certainty and facility, they may derive the diſcovery of new materials, and of the moſt advantageous means of employing them.

The art of painting, alſo, will receive great advantage, from an accurate and preciſe conception of the principles, by means of which the colouring matters, endued with a reflective power, may be diſtinguiſhed from others which tranſmit the rays, but do not reflect them.

The works of many painters greatly excel in the clearneſs and brightneſs of their colouring:* but

* Several of the greateſt maſters practiſed a method of colouring, which was, in ſome reſpects, conformable to the

but, it is unqueſtionable that a ſcientific knowledge of the nature of the colours, which they uſed, would have enabled even the greateſt maſters to have communicated, to thoſe works, a ſtill higher degree of excellence.

I ſhall not regret the labours which I have beſtowed on the ſubject of theſe pages, if they contribute to the advancement of thoſe uſeful and elegant arts, which are of much importance to a commercial nation; or if, by the diſcloſure of phyſical truths, they extend the bounds of ſcience, or open new paths to its improvement.

the true principles of optics, and of their art. One of our moſt eminent painters has obſerved, from a minute and accurate examination of ſome of the moſt capital pictures of Titian, Tintoret, Paul Veroneſe, and other Italian, Flemiſh, and Dutch maſters, that they painted with tranſparent colours, upon a white ground. This practice was carried to the higheſt degree of perfection by Correggio. That great colouriſt grounded his pictures with black and white only: and by the delicacy, clearneſs, and brilliancy of the tranſparent colours, which he laid on the grounds thus prepared, he gave to his compoſitions a peculiar force and relief, and a near reſemblance of nature. Few modern artiſts have been able to comprehend the means, by which thoſe effects were produced. Leonardo Da Vinci, in his inſtructive Treatiſe of Painting, recommends the uſe of white grounds, and tranſparent colours, as the true method of procuring the moſt brilliant colouring. Cap. 100. "Sempre à quelli colori, che "vuoi che habibno bellezza, prepararai prima il campo "candidiſſimo, e queſto dico de' colori che ſono tranſpa-"renti, perche a quelli che non ſono tranſparenti, non "giova campo chiaro."

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EXPERIMENTS *and* OBSERVATIONS *on* FERMENTS *and* FERMENTATION; *by which a* MODE *of exciting Fermentation in* MALT LIQUORS, *without the Aid of* YEAST, *is pointed out; with an* ATTEMPT *to form a new Theory of that Procefs.* *By* THOMAS HENRY, F. R. S. *Read April* 20, 1785.

Nec manet ulla fui fimilis res; omnia migrant;
Omnia commutat Natura et vertere cogit.

LUCRETIUS.

OF all the proceffes of chemiftry, there is, perhaps, none, the phænomena of which have been lefs fatisfactorily explained, than thofe of Fermentation. The writers on Chemiftry have been content to defcribe the feveral appearances, the progrefs and refult of fermentation, and have declined any inquiry into its primary caufes, or into the mode by which the changes, induced by it, are effected in bodies, which are the objects of its action.

Within thefe few years, great changes have taken place in the theory of Chemiftry. The

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important discoveries of Black and Priestley, and of several other philosophical chemists, who have endeavoured to emulate their examples, have happily explained many of the operations of chemistry, which were, before, wholly unintelligible: and the present time forms one of the most distinguished æras in the history of that science. We now understand the nature of lime and of alkalis; the difference between a metal and its calx; the cause of the increase of weight in the latter, and of its decrease when returned to a metallic form. The constitution of atmospheric air has been demonstrated—Various gases resembling air, in many points, but differing from it in others, have been discovered; and, among these, an ætherial fluid, superior in its properties to common air, and capable of supporting life and combustion more vigorously and durably. Our acquaintance with this pure fluid, which forms the vital part of common air, seems to promise much enlargement to our chemical knowledge, in the investigation of its various combinations; and we have already derived much information, relative to the constitution of the acids, and of water, from the researches of philosophers into the nature of pure air.

Of the gases which have so much engaged the attention of the pneumatic chemists, fixed air, or, as it has more properly been denominated by

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Sir Torbern Bergman, aërial acid, was that which firſt attracted their notice. This gas which had been remarked, even by Van Helmont, to be diſcharged, in great quantities, from liquors, in the vinous fermentation, was found by Dr. Prieſtley, to be again miſcible, with them; and he proved that, on the preſence of this gas, the briſkneſs and pleaſantneſs of theſe liquors depended, and that, when deprived of it, they became vapid and flat.

But though the Hon. Mr. Cavendiſh had proved the ſeparation, and aſcertained the quantity of this gas, diſcharged in fermentation, and though Dr. Prieſtley had early made the abovementioned obſervations, it does not appear to have occurred to theſe philoſophers, that this gas was the exciting cauſe, as well as the product, of fermentation.

It is a fact well known to brewers of malt liquors, that wort, contrary to what takes place in liquors more purely ſaccharine, as the juice of the grape, cannot be brought into the vinous fermentation, without the addition of a *ferment*; for which purpoſe yeaſt or barm, which is a viſcid frothy ſubſtance, taken from the ſurface of other maſſes of fermenting liquor, has been, commonly, uſed.

But the nature of this ſubſtance, much leſs its mode of action, has not been conſidered, with

that degree of attention, which one would have expected should have been excited by so extraordinary an agent. We are told indeed that, a vinous ferment induces the vinous, that, a ferment of an acetous kind brings on the acetous fermentation, and a putrid one, that fermentation which ends in putrefaction. But we receive no more information, relative to the manner in which they produce these effects, than we do with regard to fermentation itself.

Before I endeavour to deliver any theory of ferments or of fermentation, I shall relate a number of facts which, have led to a few thoughts on the subject; and having mentioned the phænomena attendant on the process, as described by other chemists, shall then proceed to offer an hypothesis, with the greatest diffidence—a diffidence which nothing could enable me to surmount, but the kind indulgence I have so often experienced in this Society. And on no occasion have I stood more in need of their candour than on the present one; as the obscurity and intricacy of the path, on which I am entering, the almost total want of guides, and my inadequate abilities to clear away the obstacles, throw light on the dark parts, and point out those that may be traversed with ease and certainty, place me in a situation truly difficult. Indeed I was in hopes to have rendered what I have to offer, less imperfect, but my son's unfortunate accident, has

has ſo engaged my thoughts, and added ſo much to my neceſſary avocations, that I have been able to devote but a ſmall portion of my time to ſcientific purſuits.

Soon after Dr. Prieſtley had publiſhed his method of impregnating water, with fixed air, I began to prepare artificial Pyrmont water, by that means; and early obſerved that water, ſo impregnated, though it at firſt ſhewed no ſparkling when poured into a glaſs; yet after it had been kept in a bottle, cloſely corked, for ſome days, exhibited, when opened, the ſparkling appearance of the true Pyrmont water.* This I attributed, and perhaps not unjuſtly, to the gas, which had been more intimately combined with the water, and reduced to a kind of latent ſtate, recovering its elaſticity and endeavouring to eſcape.

Having, one day, made ſome punch with this water, and, having about a pint of it remaining, after my friends had retired, I put it into a bottle, capable of containing a quart, and corked the bottle. On opening it, at the diſtance of three or four days, the liquor, when poured out, creamed and mantled, like the briſkeſt bottled

* Various methods have ſince been deviſed of forcing ſuch a quantity of gas to combine, or, at leaſt, to mix, with water, as immediately to communicate to it this appearance.

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cyder. An old gentleman, to whom I gave a half pint glafs full of it, called out in raptures to know what delicious liquor he had been drinking, and earneftly defired that, if I had any more of the fame, I would give him another glafs.

Dr. Prieftley, as has been already mentioned, had informed us that fixed air, thrown into wine or malt liquor, grown vapid, reftored to them their brifknefs and pleafant tafte. On impregnating fome vapid ale with fixed air, I was difappointed in not finding the effect, immediately produced. But after bottling the ale and keeping it clofely ftopped for four or five days, it was become as brifk as ale, which, in the common way, has been bottled feveral months.

In the year 1778 I impregnated, with fixed air, a quantity of milk whey, which I had clarified for the purpofe of preparing fome fugar of milk, and bottled it. In about a week, the whey in one of the bottles, which had been fo loofely corked, that the liquor had partly oozed out, was remarkably brifk and fparkling. Another bottle, which was not opened till the fummer of 1782, contained the liquor, not in fo brifk a ftate, but become evidently vinous, and without the leaft acidity, perceptible to the tafte.

I now began to fufpect that fixed air is the efficient caufe of fermentation; or, in other words, that the properties of yeaft, as a ferment, depend on the fixed air it contains; and that yeaft is little elfe than fixed air, enveloped in the

the mucilaginous parts of the fermenting liquor. I therefore determined to attempt the making of artificial yeaſt.

For this purpoſe, I boiled wheat flour and water to the conſiſtence of a thin jelly, and, putting the mixture into the middle part of Nooth's machine, impregnated it with fixed air, of which it imbibed a conſiderable quantity. The mixture was then put into a bottle, looſely ſtopped, and placed in a moderate heat.

The next day the mixture was in a ſtate of fermentation, and, by the third day, had acquired ſo much of the appearance of yeaſt, that I added to it a proper quantity of flour, kneaded the paſte, and after ſuffering it to ſtand, during five or ſix hours, baked it, and the product was bread, tolerably well fermented.

I now determined to make a more ſatisfactory experiment. The wort, obtained from malt, it is known cannot be brought into a ſtate of fermentation, without the aid of a ferment; for which purpoſe yeaſt is always uſed. If, therefore, by impregnating wort with fixed air, I could bring on the vinous fermentation; if I could carry on this fermentation ſo as to produce ale, and, from the ale, procure ardent ſpirit, I imagined that I ſhould be able to announce to the world, a mode of procuring newly fermented liquors, in moſt climates, and in moſt ſituations.

I, accordingly, procured, from a public houſe,

two gallons of ſtrong wort. It had a diſagreeable bitter taſte, owing either to bad hops, or to ſome ſubſtitute for hops. A large part of the liquor was impregnated, in Nooth's machine, with fixed air, which it ſeemed to abſorb very rapidly and in large quantity. When it was thus impregnated, it was mixed with the other part, and poured into a large earthen jug, the mouth of which was ſtopped with a cloth; and placed in a degree of heat, varying from 70°. to 80°. In twenty-four hours the liquor was in briſk fermentation, a ſtrong head of yeaſt began to collect on its ſurface; and, on the third day, it appeared to be in a ſtate fit for tunning. It was therefore put into an earthen veſſel, ſuch as is uſed in this country, by the common people, as a ſubſtitute for a barrel, for containing their ſmall brewings of fermented liquors. During the ſpace of near a week, previous to the ſtopping up of this veſſel, much yeaſt was collected on its ſurface, and occaſionally taken off; and by means of this yeaſt, I fermented wheat flour, and procured as good bread, as I could have obtained, by uſing an equal quantity of any other yeaſt.

The veſſel was now ſtopped up; and, in about a month, tapped. The liquor was well fermented, had a head or cream on its ſurface, and though, as might be expected from the deſcription of the wort, not very pleaſant, yet as much

much ſo, as the generality of the ale brewed at public houſes.

A part of the ale was ſubmitted to diſtillation; and, from it, a quantity of vinous ſpirit was produced, which is ſubmitted to the examination of the Society. But, the veſſel being broken, before the diſtillation was finiſhed, the quantity it would have yielded was not aſcertained. However, that which was obtained, appeared not to differ much in quantity, from what an equal portion of common ale would have afforded.

As I had loſt my notes, and was obliged to make out the preceding account, from memory, I deſigned to repeat the experiments again; but various engagements prevented me, till the latter end of Auguſt 1784. Of theſe experiments the following notes are taken from my journal.

Auguſt 30, I procured two gallons of common ale wort, two quarts of which were, in the evening, impregnated, but not ſaturated, with fixed air. The impregnated liquor was, then, added to the other part, and, about midnight, placed, in a large jug, within the air of the kitchen fire, where it remained during the night. In the morning no ſigns of fermentation. At five o'clock P. M. only a ſlight mantling on the ſurface. Apprehending the quantity of gas to have been too ſmall, a bottle, with a perforated ſtopper and valve, containing an effervеſcing mixture of chalk and vitriolic acid, was let down

into

into the wort. At nine o'clock, the difcharge of air, from the bottle, was going on brifkly, and the wort feemed to be fermenting. At eleven o'clock the bottle was withdrawn, the fermentation being commenced, beyond a doubt; the furface of the liquor having a pretty ftrong head—Temperature of the wort 80°—at the outfide of the veffel 78°.

September 1ft, feven o'clock, A. M. the fire having been low during the night, the fermentation was lefs brifk—temperature of the wort reduced to 72, and probably had been lower during the night, as the fire was now increafed. The liquor was ftirred up, placed in a fituation where the thermometer pointed to 82°. and the effervefcing mixture was again immerfed. It was withdrawn at noon, and the thermometer ftanding at 92°, the wort was removed farther from the fire—At four o'clock, P. M. the head of yeaft was ftrong, and at eleven o'clock was increafed.

September 2d, nine o'clock, A. M. the liquor was judged to be in a proper ftate for tunning. It was accordingly removed into the veffel, before defcribed, and carried into the cellar at eleven—at noon, a high head of yeaft was running over the top of the veffel—fome of it was taken off, and in two hours the head was equally ftrong.

September

September 3d, the fermentation proceeded regularly this day; and on the 4th I had collected ſo much yeaſt as to make a loaf with it, which, when baked, weighed about two pounds. The loaf was well fermented, good bread, having no peculiar taſte, except a ſlight bitterneſs, proceeding from the wort having had too large a proportion of hops. Though, from the time in which the yeaſt had been collecting from ſo ſmall a quantity of liquor, its fermenting power might have been expected to have been impaired.

September 5th the liquor was again covered with a plentiful head of yeaſt; and the fermentation was ſuffered to proceed to the 12th, when the veſſel was cloſed, in the uſual manner.

I intended, in a few weeks, to have committed the liquor to diſtillation; but my thoughts were unfortunately directed, to an object which engaged my moſt anxious attention; and my wort was neglected till the latter end of February; when, on tapping the veſſel, the liquor, from having been kept ſo long, under ſuch diſadvantageous circumſtances, and, perhaps, from too great heat in the fermentation, and the too long continuance of it, had paſſed from the vinous to the acetous ſtate, and was become excellent allegar.

As I had obtained a vinous ſpirit from the former parcel of wort, I was not ſorry for this event, as it was going a ſtep farther than I expected,

pected. For I had now obtained yeaſt, bread, ale, ardent ſpirit, and acetous acid. A ſpecimen of the laſt is now produced to the Society.

I flatter myſelf that theſe experiments may be of extenſive utility, and contribute to the accommodation, the pleaſure, and the health, of men, in various ſituations, who have hitherto, in a great degree, been precluded from the uſe of fermented liquors; and be the means of furniſhing important articles of diet and of medicine. Not only at ſea, but in many ſituations in the country, and at particular ſeaſons, yeaſt is not to to be procured. By the means I have ſuggeſted, in theſe experiments, freſh bread and newly fermented malt or ſaccharine liquors may, at any time be procured; and of how much importance, this may be, and how great the improvement to the malt decoctions recommended by the late Dr. Macbride, I ſhall not at preſent ſtay to expatiate on; as the ſubject may be too much connected, with the practical part of phyſic, to come within the limitations drawn by the Society. But, in domeſtic œconomy, its uſes are very obvious; and perhaps in none more ſo, than the ready mode, which the preceding experiments teach, of reviving fermentation when too languid—the ſinking of a bottle, ſuch as I have deſcribed, in my Eſſay on the Preſervation of Water, at Sea, &c. * with an effervеſcing mixture of chalk and vitri-

* London, 1781. See alſo, Plate 1, Fig. 1. Vol. II.

olic

olic acid, appearing to be fully adequate to the purpofe, and being, I believe, fufficient for impregnating the wort, without any other contrivance. This difcovery therefore may, perhaps, be of no fmall utility in public breweries, and I would recommend it to the attention of perfons concerned in the brewing trade.

Let us now proceed to defcribe the circumftances neceffary to, and the phænomena attending fermentation, as defcribed by chemical writers; and then endeavour to form fome theory which may account for them.

Sugar, the juices of ripe fruit, and malt are all more or lefs difpofed to run into fermentation. But before this can take place, it is neceffary they fhould be diluted with water, fo as to bring them to a liquid ftate. A due degree of heat is alfo requifite, as the fermentation fucceeds beft when the temperature varies from 70 to 80 degrees.

When the fermentation takes place, a brifk inteftine motion is obfervable in the liquor; it becomes turbid, fome fæculæ fubfide, while a frothy fcum arifes to the furface. A hiffing noife is obferved, and a quantity of gas is difcharged, which has been proved to be fixed air. The liquor acquires a vinous fmell and tafte; and, from being heavier, becomes fpecifically lighter, than water. During the progrefs of the procefs, the temperature of the liquor

is

is higher than that of the ſurrounding atmoſphere, with which it is neceſſary that a communication be preſerved. After ſome days, theſe appearances begin to decline. If the proceſs be rightly conducted, and ſtopped at a proper period, a liquor, capable of yielding vinous or ardent ſpirit, is the reſult. If the proceſs has been too ſlow and the degree of heat inſufficient, the liquor will be flat and ſpiritleſs; but, if theſe have been too rapid and exceſſive, it will paſs into the acetous fermentation, to which indeed it is continually tending. But the more ardent ſpirit is generated, the leſs ſpeedy will be the change to the acetous ſtate.

During the progreſs of the acetous fermentation, which will even proceed in cloſely ſtopped veſſels, no ſeparation of air is obſervable, nor any ſtriking phænomena. The liquor gradually loſes its vinous taſte, and becomes ſour, and a groſs ſediment falls to the bottom; while a quantity of viſcid matter ſtill remains, enveloping the acid, which may be ſeparated from much of the impurity by diſtillation.

The progreſs of theſe proceſſes is accelerated by the addition of ferments, to the action of which it has been ſuppoſed neceſſary, that they ſhould have paſſed through the ſtate of fermentation into which they are intended to bring the liquor to which they are added; and that it was not poſſible to bring the farinaceous infuſions into

into the vinous fermentation, without the aid of matter already in that ſtate. This the preceding experiments have proved to be an ill founded notion, as it appears that fixed air, obtained from calcareous earth by means of acids, produces the effect, as perfectly as when the ferment has been taken from a fermenting liquor.

In fermentation, it is ſaid, new arrangements take place in the particles of the liquor, and the properties of the ſubſtance become different from what it before poſſeſſed. But what theſe arrangements are, or how theſe properties are changed, we are not told. Dr. Black, I am informed, declares he is unacquainted with any ſatisfactory theory.

But perhaps facts, eſpecially ſome *late* chemical diſcoveries, may throw light on the matter, and enable us to advance ſome conjectures, that may tend, at leaſt, to lay the *foundation* of a theory.

1. Sugar is an eſſential ſalt, containing much oily, viſcid matter. During its combuſtion it repeatedly explodes; a proof that it contains not only much inflammable matter, but alſo a quantity of air. Malt is ſaccharine, united to much viſcid mucilaginous, matter.

2. If nitrous acid be added to ſugar, the inflammable principle of the latter is ſeized by the acid; the whole, or at leaſt one of the conſtituent parts of which is thereby converted into nitrous

gas,

gas, and flies off in that form. By repeated effufions of this acid, more gas is formed, and the remainder of the fugar is changed into cryftals, having the properties of an acid, fui generis, and which has been denominated, by Bergman, faccharine acid.*

3. Saccharine acid is refolvable by heat, into fome phlegm, a large quantity of inflammable and fixed air, both of which contain latent heat, and into a brownifh refiduum, amounting to $\frac{1}{10}$ of the weight of the acid. Fixed air is fuppofed to confift of pure air united to phlogifton; and inflammable air, to be almoft pure phlogifton.

4. Water is found to be formed by the union of pure air, and inflammable gas, deprived of their latent heat; for, if thefe two elaftic fluids be exploded together, in a clofe veffel, over mercury, the whole is converted into water of the fame weight, as that of the air and gas, jointly. In the procefs much heat is evolved. Again, if water, in the form of fteam, be forced to pafs through a tube, containing iron fhavings, ftrongly heated, the water, according to Meffrs. Watt, and Lavoifier, is decompofed; the phlogifton paffes off, united with heat, in the form of inflammable gas, while the *humor*, or dephlogifticated water, unites to the calx of the metal, from which it may be again obtained, in the

* Bergmani Opufcula Chemica, vol. I. Art. de Acido Sacchari.

form

form of pure air, or of aërial acid, according to the degree, in which the calx has been dephlogisticated. It has been already observed, that saccharine matter cannot be brought to ferment without water.*

5. A vinous liquor, on distillation, yields an ardent spirit.

6. Spirit of wine has had the whole of its inflammable part dissipated by combustion; after which, Mr. Lavoisier found the watery part increased in weight, from sixteen to eighteen ounces, by the absorption of the air, decomposed by the combustion.

7. The residuum, after the distillation of ardent spirit from fermented liquors, is *acid*.

8. Mr. Lavoisier has supposed pure air to be the acidifying principle of all the acids; and that their difference, from each other, consists in the basis united to this pure air.

As our experiments were made with an infusion of malt, and with fixed air, employed as a ferment, let us endeavour to account for the several phænomena and results of fermentation, as appearing in these experiments.

* More recent experiments having rendered the facts, contained under this article, more doubtful than they appeared to be, at the time this paper was first published; and the inferences, deduced from them, not being altogether satisfactory to the Author's mind, he has withdrawn them in the subsequent part of the Essay.

The wort being impregnated with fixed air, and placed in ſuch a ſituation, as to bring it to the degree of heat, at which wort is commonly mixed with yeaſt, the gas, for ſome time remains in a latent, or quieſcent ſtate; but, from its tendency to recover its elaſtic form, aided by heat, it preſently begins to burſt from the bonds in which it was confined. By this effort, the mucilaginous parts of the infuſion are attenuated; the ſaccharine matter is developed; and, the ſame cauſe, continuing to act, the conſtituent parts of that matter are ſeparated, and, the particles of the component principles, being by this means placed beyond the ſphere of their mutual attraction, begin to repel each other. A large quantity of phlogiſton is diſcharged, together with ſome pure air. The greateſt part of the inflammable principle enters into a new combination, joining the baſis of the vegetable acid, while another, but much ſmaller portion, uniting, in its naſcent ſtate, with the pure air, forms fixed air; which, in its attempt to eſcape, carries up with it much of its viſcid confinement. In the converſion of the pure into fixed air, a conſiderable portion of heat is rendered ſenſible. And this heat contributes to the farther decompoſition of the ſaccharine ſubſtance. The viſcid matter, collecting on the ſurface, prevents the eſcape of too much of the gas, and promotes its reabſorption, that, thereby, the briſk and agreeable taſte of the liquor

liquor may be formed; and that this gas may contribute, in a future ſtage of fermentation, to the conſtitution of the acetous acid.

The veſſel being ſtopped, ſome of the ſaccharine matter, being not decompoſed, the liquor will continue to have a ſweetiſh taſte. But, the fermentation ſtill going on, in a more gradual manner, the liquor will become leſs ſweet, and, proportionably, more impregnated with ardent ſpirit; and the fæculæ ſubſiding in the form of lees, it will be now fully fermented, mellow, and pellucid.*

But, if the ſaccharine matter be too much diluted, or the veſſel be placed in a warm ſituation, the liquor will then paſs from the vinous, to the acetous, fermentation.

In the formation of the ſaccharine acid, by means of nitrous acid; the laſt is ſuppoſed, by carrying off the phlogiſton of the ſugar, to develope the ſaccharine acid. Or, according to Mr. Lavoiſier's hypotheſis, one of the conſtituent parts of the nitrous acid performs this office, while the other, or pure air, uniting to the peculiar baſis, contained in the ſugar, forms ſaccharine acid.

* In the fermentation of wine a ſubſtance is depoſited at the ſides and bottom of the caſk called tartar; which is lately diſcovered to conſiſt of pure vegetable alkali, united to a ſuperabundant quantity of a peculiar acid. But as this is not produced by malt liquors, it has not been noticed in the eſſay.

So in the acetous fermentation, if it happen that the phlogiſton is not in ſufficient quantity, or the force with which it is combined in the liquor be weakened, by a long application of heat or other cauſes; it will begin to ſeparate from the baſis of the vegetable acid, and the ardent ſpirit will be decompoſed, and in proportion as the inflammable principle is ſeparated, the baſis, now left at liberty, will unite with the fixed air, and the reſult will be acetous acid. It is probable alſo that during the progreſs of the acetous fermentation, an abſorption of pure air from the atmoſphere, takes place.

Thus the acetous fermentation acts in a manner, in ſome reſpects, analogous to the action of nitrous acid on ſugar. In the latter caſe, the phlogiſton is ſeparated more rapidly, but imperfectly; and the acid, reſulting from the proceſs, is that called ſaccharine acid. In the former, the changes are more ſlowly produced; the phlogiſton flies off more gradually; but the ſame cauſe continuing to operate, the dephlogiſtication is more complete than in the other caſe, and vinegar is produced. And perhaps it may ſerve to give ſome appearance of probability to the above theory, to recollect, that the reſiduum of fermented liquors, after the ſeparation of the ardent ſpirit, which appears to be water ſuperſaturated with phlogiſton, is *acid.** I have

* In the former edition of theſe Memoirs, I had ſuppoſed a decompoſition of the water employed to take place, and that

I have avoided carrying theſe reflections to the phænomena which appear in the putrid fermentation, as not ſo immediately connected with ſaccharine ſubſtances; and from a conviction that I have already engroſſed too much of the Society's time.—If I have contributed any thing to their entertainment, or that may tend to enlarge the bounds of ſcience, I ſhall eſteem myſelf happy; and, more ſo, if what has been advanced may prove uſeful and advantageous to my fellow-creatures.—Senſible that one ſuch fact is of more real worth, than the moſt ingenious and well-wrought hypotheſis.

that it was reſolved into the two conſtituent parts, viz. pure, and inflammable air, of which it has been imagined, by Mr. Lavoiſier, and others, to be formed. But notwithſtanding a late experiment, made by this ingenious philoſopher, the reſult of which ſeems favourable to my hypotheſis, I had, for various reaſons, relinquiſhed this part of it, before I had the pleaſure of peruſing Mr. Rigby's Chemical Obſervations on Sugar, which contain ſome very candid and weighty objections to the doctrine. Among theſe Mr. Rigby remarks, that it never has been proved that water does conſiſt of pure and inflammable air, and ſince the publication of his Treatiſe, the evidence againſt the preſumption is become ſtrong by Dr. Prieſtley's late Experiments, by which it appears, that the water, produced in the exploſion of theſe airs, is not a new compound, from a union of the two, but a ſeparation of the water previouſly contained in them. The degree of heat, Mr. Rigby obſerves, ſeems inadequate to the ſuppoſed effect, but fermentation in many inſtances, which might be adduced, brings on by ſlow degrees, changes ſimilar to thoſe effected, more inſtantaneouſly, by the action of heat.

On the ORIGIN *of* ALPHABETICAL CHARACTERS. *By* GILBERT WAKEFIELD, B. A. *late Fellow of Jesus College, Cambridge. Read March* 10, 1784.*

AT this period of time, when the human mind has acquired ſo much honour by the introduction of ſuch aſtoniſhing improvements, into the various departments of philoſophy and ſcience, beyond the example of former ages; thoſe ſpeculations, which tend to aggrandize the dignity of reaſon, are received with avidity, and admitted with a readier acquieſcence. We are apt to conclude, that the ſame ingenuity and ſtrength of faculties, which have been able to inveſtigate the ſublime laws of the planetary ſyſtem, to adjuſt the tides, to

* The unſettled ſituation of the author, and his abſence from books, would not ſuffer him to diſcuſs the following ſubject in any other than a popular manner. The moſt ſatisfactory authorities, however, might be produced for every aſſertion of importance, and much more might have been alledged to the purpoſe of the queſtion. But the reader muſt condeſcend to take the attempt, as it is offered to his notice. With reſpect to the *Armenian* language, with which the author is not acquainted, it is ſaid to be of more modern date, than the other oriental tongues, and to have a great affinity to the *Greek*.

diſentangle

disentangle the rays of light, to detect the electric fluid, and to extend their researches into the remotest regions of mathematic science; must be adequate to any attainments, and discoveries whatsoever. Nor has any disputable topic of enquiry been accepted more implicitly of late, even by men accustomed to hesitate and to examine, than the gradual discovery of *Alphabetical Characters* by the successive exertions and accumulated experience of mankind—To call in question a maxim so generally believed, may appear, in the judgement of philosophers, to savour of superstition and credulity: but, perhaps, it will be found, that the evidence in favour of this maxim, bears no proportion to the confidence, with which it is embraced. As a man, I rejoice in whatever is honourable to our nature: but various scruples have ever forbidden my assent to this popular article of belief. I will state my objections to it in a plain and popular manner with all possible perspicuity and conciseness; and then submit the determination of this question to the judgement and candour of this audience.

I. The five first books of the *Old Testament* are, I believe, acknowledged by all to be, not only the most ancient compositions, but also, the most early specimens of *Alphabetical Writing*, at present existing in the world. Now, if alphabetical writing be indeed the result of

human ingenuity, one great peculiarity diſtinguiſhes it from all other *human inventions* whatſoever: the very firſt effort brought it to perfection. All the ſagacity and experience of ſucceeding generations, illuſtrated as they have been by a vaſt influx of additional knowledge, beyond the moſt accompliſhed of their predeceſſors, have been unable to ſuperinduce any real improvement upon the *Hebrew* alphabet. This ſeems to me a ſingularity utterly irreconcileable to the common hypotheſis: at leaſt, I am acquainted with no plauſible anſwer to this objection.

Should any one reply, "that *alphabetical* "*characters* may have been in exiſtence many ages "prior to the date of theſe ſpecimens in the "Scriptures, but that the more ancient memori- "als, in which they were exhibited, have periſhed "by the deſolations of ignorance and the viciſſi- "tudes of time;" I muſt demur at an argument that advances no premiſes of ſufficient validity to authenticate this concluſion. For, 1. It is mere *affirmation*, without the leaſt ſhadow of hiſtorical teſtimony to give it countenance. 2. To wave the authority of the *Jewiſh* ſcriptures upon this point; (which, however, I muſt beg leave to obſerve, is corroborated by abundant evidence from philoſophy and experience, as well as hiſtory) that ſimplicity of manners, predominant in the early ages, ſo obſervable in the accounts delivered

down

down by ſacred and profane hiſtorians; the confeſſed mediocrity of their intellectual acquirements, and the confined intercourſe of nations with each other, which would render ſuch an expedient leſs neceſſary, and therefore leſs likely to be diſcovered: all theſe conſiderations ſeem to argue with no little cogency, that ſo complex, ſo curious, ſo wonderful, ſo conſummate a deviſe as that of *alphabetical writing* could hardly be *firſt* detected by a race of men, whoſe wants were few, whoſe advantages were circumſcribed, and whoſe ideas were commenſurate to their ſituation. This poſition, therefore, conjectural as it is, and unſubſtantial, ſeems unworthy of further animadverſion.

II. If *alphabetical writing* were a *human invention*, the natural reſult of ingenuity and experience; might we not expect, that different nations, would have fallen upon the ſame expedient, independently of each other, during the compaſs of ſo many ages: when the faculties of the mind are equally capable at all times, and in every corner of the univerſe, and when the habits of life and modes of thought inevitably bear ſo great a reſemblance to each other in ſimilar ſtages of ſociety? This I ſay, were but a reaſonable expectation: which however, correſponds not to the event. For *alphabetical writing*, as now practiſed by every people in the univerſe, may be referred to *one* common original. If this

this propoſition can be proved, the argument from ſucceſſive derivation, without a ſingle inſtance of independent diſcovery, muſt be allowed to amount to the very higheſt degree of probability in my favour: and the common ſuppoſition will appear perfectly gratuitous, with the incumbrance alſo of this great paradox: "you tell us, I might ſay, of an invention, "which is the regular conſequence of refinement "in ſociety, nothing more than a gradual ad-"vancement from what is plain to what is "complex; by a ſimilar proceſs, purſued by the "mind in all its exertions for improvement: and "yet, we can perceive no reaſon to conclude, "that any community but one, and that in no "wiſe diſtinguiſhed by any vaſt ſuperiority of "inventive genius, or the improvements intro-"duced by them into common life, ever com-"paſſed this diſcovery; though the human "powers have been uniformly the ſame, and the "conduct of ſociety has been greatly ſimilar in "different nations at different periods of time."

Let us conſider then, how the evidence ſtands in this caſe: only premiſing, that, where a continuity of tranſmiſſion appears to have taken place, ariſing from the intercourſe of nations with each other; and where the words are the ſame, the grammatical conſtruction, and other minute peculiarities of compoſition much alike, in two languages; theſe languages are of the ſame

ſame texture: and that *alphabetical compoſition*, attended by theſe circumſtances of reſemblance, muſt flow from one ſource: eſpecially, if the difference in the *alphabetical marks* of theſe two languages ſhould be no objection, but may be accounted for upon reaſonable principles.

It will be readily allowed then, I preſume, that no modern *European* nation, excluſive of the *Turkiſh* empire indebted to the *Greeks* and *Arabians*, ſeparately invented *alphabetical writing*: we all derived, without any doubt, this art from the *Romans*. The *Romans* never laid claim to the diſcovery: they aſcribed all their literary advantages to the *Greeks*. This accompliſhed people acknowledge, with one voice, to have received the art from the *Phœnicians*; who, as well as their coloniſts the *Carthaginians*, are known by the learned to have ſpoken the *Hebrew* language, or a dialect ſcarcely varying from the original. The *Coptic*, or *Ægyptian*, wears the exacteſt reſemblance in the majority of its characters to the *Greek*; they, therefore, muſt be referred in all reaſon to the ſame origin. The *Chaldee*, *Syriac*, and later *Samaritan*, are dialects of the *Hebrew*, without any conſiderable deviation, or many additional words. The *Æthiopic* differs more from the *Hebrew*, but ſtill leſs than the *Arabic*. Theſe languages, however, notwithſtanding ſuch deviations, have iſſued from the ſame ſtock; as the ſimilarity of their formation, and

and the numberlefs words, common to them all, demonftrably evince: and the *Perfic* has a clofe affinity to the *Arabic*. Alterations would naturally be introduced, proportionate to the civilization of the feveral poffeffors, and their feparation from the other nations: and this will account for the fuperior copioufnefs of fome above the reft. So then, not to determine which was the more ancient language, the *Hebrew*, *Syriac*, or *Arabic*, a queftion of no importance on this occafion; all the languages in ufe amongft men, that have been conveyed in *alphabetical characters*, have been the languages of people, connected ultimately or immediately, with thofe, who have handed down the earlieft fpecimens of writing to pofterity. And when the languages of the *Eaftern* nations are fo fimilar—when fo curious an art would be, in all probability, the firft improvement communicated by one people to another—is it not morally certain, that *alphabetical writing* originally centered in one people? For length of time has deprived us of exprefs hiftorical teftimony in this cafe.

Indeed, this propofition feems to be fufficiently afcertained by another argument; that is from the famenefs of the artificial denominations of the letters in the *Oriental*, *Greek*, and *Latin* languages; accompanied too by a fimilar arrangement: *Alpha*, *Beta*, and fo on.

But

But in oppoſition to this evidence, ſome will argue againſt all poſſible admiſſion of our concluſion, by alledging the entire diſſimilarity of characters employed by the ancients to diſcriminate their letters. "Why ſhould not one nation, " it will be urged, adopt from the other the " mode of expreſſing the art, as well as the " art itſelf? To what purpoſe the trouble of " inventing another ſyſtem of *characters?*"

Various anſwers may be returned to this objection.

1. We know, from the inſtance of our own language, what diverſities may be introduced in this reſpect merely by length of time, and an intercourſe with neighbouring nations. And ſuch an effect would be much more likely to take place, before the art of printing had contributed to eſtabliſh an uniformity of character. For, when every work was tranſcribed by the hand, we may eaſily imagine how many variations would ariſe from the fancy of the ſcribe, and the mode of writing ſo conſtantly different in individuals. What *two* perſons write without the plaineſt ſymptoms of peculiarity?

2. Vanity might ſometimes give occaſion to this diverſity. When an individual of another community had become acquainted with this wonderful artifice, he might endeavour to recommend himſelf to his own people, as the deviſer of it: and, to evade detection, might have re-

courſe

courſe to the ſubſtitution of new ſymbols. But let no more credit be given to this conjecture than it deſerves.

3. The characters of the *alphabet* might, ſometimes, be accommodated, as much as poſſible, to the ſymbolical marks already in uſe amongſt a particular people. Theſe having acquired a high degree of ſanctity, by the uſe of many generations, would not be eaſily ſuperſeded, without the aid of ſome ſuch contrivance, by an adventitious practice.

4. But I have more than conjecture to offer in ſupport of this argument; even the teſtimony of an ancient hiſtorian: whoſe account will ſerve as a general evidence in this caſe, and may lead us to conclude, that ſimilar deviations may have taken place, amongſt other claſſes of men, as well as in that inſtance, which he particularly ſpecifies from his own knowledge.

Herodotus, in one part of his hiſtory, has the following relation:

" Thoſe *Phœnicians*, who came with Cadmus,
" introduced many improvements among the
" *Greeks*, and *alphabetical writing* too, not known
" in my opinion, to the *Greeks* before that period.
" At firſt they uſed the *Phœnician* character: but
" in proceſs of time, as the pronunciation altered,
" the ſtandard of the letters was alſo changed.
" The *Ionian Greeks* inhabited at that time the
" parts adjacent to Phœnicia: who, having

" received

" ceived the art of *alphabetical writing* from the
" *Phœnicians*, uſed it, with an alteration of ſome
" few characters: and confeſſed ingenuouſly, that
" it was called *Phœnician*, from the introducers
" of it. And I have ſeen myſelf the characters
" of *Cadmus* in the temple of *Iſmenian Apollo* at
" *Thebes* in *Bœotia*, engraven upon tripods, and
" very much reſembling the *Ionian* characters."

5. The old *Samaritan* is preciſely the ſame as the *Hebrew* language: and the *Samaritan Pentateuch* does not vary by a ſingle letter in *twenty* words from the *Hebrew*. But the characters are widely different: for the Jews adopt the *Chaldaic* letters, during their captivity at *Babylon*, inſtead of the characters of their forefathers. This difficulty then ſeems to have been ſufficiently conſidered.

III. What we know of thoſe nations, who have continued for many centuries unconnected with the reſt of the world, ſtrongly militates againſt the hypotheſis of the human invention of *alphabetical* writing. The experiment has been fairly made upon the ingenuity of mankind for a longer period, than that which is ſuppoſed to have produced *alphabetical writing* by regular gradations: and this experiment determines peremptorily in our favour.

The *Chineſe*, a people famous for their diſcoveries and mechanical turn of genius, have made ſome advances towards the delineation of

of their ideas by arbitrary ſigns; but have never-theleſs been unable to accompliſh this exquiſite device: and after ſo long a trial, to no purpoſe, we may reaſonably infer, that their mode of writing, which is growing more intricate and voluminous every day, would never terminate in ſo clear, ſo comparatively ſimple, an expedient, as that of *alphabetical characters*.

The *Mexicans*, alſo, on the new Continent, had made ſome rude attempts of the ſame kind, but with leſs ſucceſs than the *Chineſe*.

We know alſo, that *Hieroglyphics* were in uſe, among the *Ægyptians*, poſterior to the practice of *alphabetical writing* by the *Jews*: but whether the *Epiſtolography*, as it is called, of the former people which was in vogue, during the continuance of *Hieroglyphics*, might not poſſibly be another name for *alphabetical writing*, I will not take upon me to decide.

Now what will our adverſaries reply to this? They will pertinaciouſly maintain, that *alphabetical writing* is a *human invention*: and yet all thoſe nations, who have been converſant with this expedient, are diſcovered to have derived it from the ſame original, from ſome one people in the *Eaſt*, whoſe means of attaining it we cannot now find out; but are compelled to conclude from analogy, and the experience of other nations, that their imagination, as it was not more fertile, was not more ſucceſsful, than that of their neighbours.

Again:

Again: Where large communities have flourished for ages, but unconnected with those countries, which enjoyed this advantage, their own solitary exertions were never capable of effecting this capital discovery. Is it possible for presumptive evidence to be more satisfactory than this?

IV. Lastly, We will consider the argument, upon which the commonly received supposition entirely depends: that is, the natural gradation through the several species of symbols, acknowledged to have been in use with various people, terminating, at last, by an easy transition, in the detection of *alphabetical characters*. I cannot see this regularity of process, this ease of transition, so clearly as some others appear to do; but let every one determine for himself from the contemplation of the several stages of emblematical representation.

1. The first method of embodying ideas, would be, by drawing a representation of the objects themselves. The imperfection of this method is very obvious, both on account of its tediousness, and its inability of going, beyond external appearances, to the abstract ideas of the mind.

2. The next method would be somewhat more general, and would substitute two or three principal circumstances for the whole transaction. So two kings, for example, engaging each other with military weapons, might serve to convey

the idea of a war between two nations. This abbreviated method would be more expeditious than the former: but what it gained in concifenefs, it would lofe in perfpicuity. The great defideratum would ftill be unatchieved. This is only a defcription, more compendious indeed, but ftill a defcription, of outward objects alone by drawing their refemblance. To this head, if I miftake not, the *picture writing* of the *Mexicans* is to be referred.

3. The next advance would be, to the ufe of fymbols: the incorporation, as it were, of abftract and complex ideas in figures more or lefs generalized, in proportion to the improvement of it. Thus, in the earlier ftages of this device, a *circle* might ferve to exprefs the *fun*, a *femicircle* the *moon:* which is only a contraction of the foregoing method. This *fymbol writing* in its advanced ftate would become more refined, but ænigmatical and myfterious in proportion to its refinement. Hence it would become lefs fit for common ufe, and therefore, more particularly appropriated to the myfteries of philofophy and religion. Thus *two feet*, ftanding upon water, ferved to exprefs an *impoffibility:* a *ferpent* denoted the oblique trajectories of the heavenly bodies: and the *beetle*, on account of fome fuppofed properties of that infect, ferved to reprefent the *fun*. Of this nature were the *Hieroglyphics* of the *Ægyptians*.

4. But

4. But this method, being too ſubtle and complicated for common uſe, the only plan to be purſued, was a reduction of the firſt ſtage of the preceding method. Thus a *dot*, inſtead of a *circle*, might ſtand for the *ſun*: and a ſimilar abbreviation might be extended to all the ſymbols. Upon this ſcheme, every object and every idea would have its appropriated mark: theſe marks, therefore, would have a multiplicity commenſurate to the works of nature, and the operations of the mind. This method alſo was practiſed by the *Ægyptians*, but has received its higheſt perfection from the *Chineſe*. Their vocabulary is conſequently interminable, and almoſt infinite: ſo that the longeſt life is ſaid to be incompetent to a complete acquaintance with it: and who does not ſee, that it may be extended to any aſſignable point whatever? Now, if we compare this amazingly tedious, and cumberſome, and prolix contrivance, with the aſtoniſhing brevity and perſpicuity of *alphabetical writing*, we muſt be perſuaded, that no two things can readily be conceived more diſſimilar; and that the tranſition, from a ſcheme conſtantly enlarging itſelf and growing daily more intricate, to an expreſſion of every poſſible idea by the modified arrangement of *four* and *twenty* marks, is not ſo very eaſy and perceptible, as ſome have imagined. Indeed, this ſeems to be ſtill rather an expreſſion of things by

correlative characters, like the fecond ftage of fymbol writing, than the notification of ideas by arbitrary figns. But, perhaps, we are not fo intimately acquainted with the *Chinefe* method, as will juftify any conclufions from it refpecting this fubject. We know, however, that it is widely different from the art of *alphabetical writing*, and infinitely inferior to it.

Till thefe objections, to the *human invention* of *alphabetical characters*, are refuted, there will be no reafon, I apprehend, to treat a different fuppofition from that generally admitted, as chimerical, and deftitute of philofophical propriety.

I will finifh this imperfect differtation by two or three remarks relating to the fubject.

1. *Pliny* afferts the ufe of letters to have been eternal. This fhews the antiquity of the practice to extend beyond the æra of authentic hiftory.

2. The caballiftical doctors of the *Jews* maintain, that *alphabetical writing* was one of the *ten* things, which God created on the evening of the fabbath.

3. Moft of the profane authors of antiquity afcribe the firft ufe of *alphabetical characters* to the *Ægyptians*; who, according to fome, received the expedient from *Mercury*; and according to others, from the God *Teuth*.

4. Is there any reafon to fuppofe, from the *hiftory* of the *human mind*, that *oral language*, which

which has been long perfect, beyond any memorials of our fpecies in heathen writers, and is coæval with man, according to the teftimony of fcripture: is there any reafon, I fay, to fuppofe, that even *language itfelf* is the effect of *human ingenuity* and *experience?*

An ESSAY *on* CRIMES *and* PUNISHMENTS. *By the Rev.* WILLIAM TURNER. *Read March* 24, 1784.

FROM the original imperfection of Human Nature in general, and the different opportunities and talents of individual men, imperfect and different judgments will neceffarily arife, fome of which, at leaft, muft confequently be errors. Thefe will lead to the formation of different difpofitions and habits; of which, thofe founded on right reafon, and a proper judgment of things, muft be good, while thofe founded on error, and a perverted judgment of things, muft, in that proportion, be depraved. Thefe different difpofitions will lead to correfpondent actions, which will be good or bad likewife; and, as far as they are the one or the other, will be proportionably ufeful or detrimental, to the

authors of them, and to the society of which they are members.

Since, then, our errors may produce so important effects to ourselves, and those with whom we are concerned, it is of the greatest consequence that we should early correct all such as may lead to hurtful actions. This will be best effected, by considering attentively our various relations with respect to other beings, the advantages we derive from such relations, and the duties incumbent upon us in consequence of them.

Now we shall find, that when man was first created, he was placed in a world so constituted, as that, by the practice of certain personal and relative duties, he might best promote his own happiness, and that of his fellow-creatures. He was thus made subject to a moral law, engraven, as it were, upon his mind, for the due observance of which he was left accountable to his Almighty Creator. But in process of time, as mankind multiplied upon the earth, and violations of this original rule of action increased continually in frequency and enormity, it became necessary for men to unite together, in distinct and separate bodies, for mutual protection and defence: and hence would arise the first forms of civil society.

Thus we find, that the human race are subject and accountable to a moral, and a political law.

At

At the head of the one, is the great (things, as the ſupreme eternal Leg Executor. At the head of the other, civil governors, who are appointed to theſe important offices in thoſe tempora ties, into which men enter during thei nuance in this world.

Each of theſe conſtitutions of governm attended with many advantages, the one pro. ting our moral, the other our political happin

With reſpect to the former, however, the eternal laws of moral obligation, with the different degrees of moral enormity, are ſo deeply engraven on the human mind by nature, and ſo forcibly republiſhed in the books of revelation, that they ſeem not ſo much the objects of ſpeculative diſquiſition: every good man is ſenſible of their obligation, and of the proper reſtrictions with which they are to be taken. But an attention to the rules by which actions are eſtimated in a political view, is highly neceſſary for all men, whatever be their moral character; ſince otherwiſe, they may be miſled by the idea, that the ſame general rules obtain both in the divine and human governments, under the political as well as the moral conſtitution; ſo that, if they be careful to keep within the bounds of ſtrict morality, they can never become amenable to the laws of civil ſociety *. This, however, is, doubtleſs, an

* Compare Judge Forſter's preface to his Reports, quoted in the laſt page of this eſſay.

ı appear from the former part of the
ſſay, the propoſed object of which is,
o point out the difference between
l political tranſgreſſions, with their re-
puniſhments: ſo far, at leaſt, as may
s to form ſome idea of the rules which
lator ſhould obſerve, in his attempts to
. the diſorders of ſociety: And,

condly, To offer ſome remarks on the pro-
tion of puniſhments to offences; and to enquire
ıto the right, utility, and ſucceſs, of *ſevere* civil
inſtitutions, particularly of capital puniſhments.

As we have divided trangreſſions, ſo we may diſtinguiſh puniſhments, into moral and political, and with reſpect to each of theſe may conſider, the *end*, the *ſubjects*, the *nature*, and the *meaſure*, of puniſhments.

I. The *end* of *all* puniſhment ſeems to be the ſame, viz. the prevention of future crimes; which is effected, either by reforming or tying up the hands of the offender himſelf, or by deterring others from the imitation of his example. This is the only ground upon which puniſhment can well be juſtified; for barely cauſing the offender to ſuffer, without producing any further effect, beſides that it is no proper ſatisfaction, ſeems to imply too much of a ſpirit of revenge or malice; which we cannot, without blaſphemy, ſuppoſe to actuate the Divine Being, and which is diſclaimed by every earthly judicature.

II. But

II. But in the *ſubjects* of puniſhment we ſhall find a much greater diſagreement; and indeed the *purpoſes* of moral and political government are ſo different, that we may naturally expect it. The purpoſe of the former is, *to train up rational beings to the higheſt moral perfection*; moral actions, therefore, alone, muſt be ſubject to its laws, which are calculated to obtain their end, by holding out rewards for actions proceeding from a good principle, and puniſhments for thoſe which ariſe from a bad one. The purpoſe of human governments, on the other hand, is merely *the preſervation of its various advantages to the ſeveral individuals of the ſtate*; and therefore, thoſe actions which tend to interrupt the enjoyment of theſe advantages, by diſturbing the peace and good order of ſociety, are the *only* ſubjects of human laws.

This diſtinction alſo neceſſarily ariſes from the different powers of the judges, as well as from the different ends of the inſtitutions. For ſince all things are open to the Deity, ſo that he can diſcover not only the actions, but even the moſt ſecret thoughts of men, he is a proper judge with reſpect to the ſpring or principle of any action. But ſince the wiſeſt human legiſlator cannot undertake to determine, with certainty, the motives which have led to the performance of any action, he muſt not pretend to puniſh according to their moral enormity; but he is an adequate judge of the political benefit or harm

harm to be expected from any particular action, or general courfe of conduct; and may therefore juftly reftrain and punifh all fuch as he is convinced are inconfiftent with the peace of that fociety over which he prefides, without enquiring whether they proceed from a good or bad moral principle. The infatuated murderer of the Duke of Buckingham was probably influenced by the beft motives to the commiffion of fuch an offence; but whether this was actually the cafe or not, nay, though the magiftrate had been fully perfuaded that it was, he would not therefore have been juftified in acquitting him, fince he would by that means have afforded an opportunity for every murderer (nay indeed for any offender) to plead the fame excufe; which, as no plea of this kind can with certainty be contradicted, would make way for the introduction of every kind of licentioufnefs, and quickly bring on the total overthrow of civil fociety. He was therefore obliged, whatever his private opinion might be, to punifh the delinquent *as guilty of an offence againft the laws of his country*; and as for the reft, muft content himfelf with the reflection, that it is in the power of the Divine Being hereafter to ratify or revoke his fentence; to reward Felton, as a lover of his country; or to recompenfe Villiers, for the misfortune he fuffered as the devoted victim of blind party-rage.

We

We may from hence infer, by the way, that the *opinions* of men cannot, with propriety, come under civil jurisdiction; every man being accountable, in this respect, to his moral governors only, his conscience and his God. It is time enough for the civil magistrate to interpose, when opinions manifest themselves in the conduct * of those who profess them; and then, if the actions they occasion are hurtful to society, he has a right to restrain *them*, without troubling himself to enquire (because he cannot determine) whether the principles which gave rise to them are true or false.

We may also remark, in a cursory manner, that this view of human punishments furnishes a strong presumptive evidence in favour of the doctrine of a future retribution, in which, all the apparent injustice of more imperfect courts will be rectified, and a society be established, whose interests will be more closely connected with the strictest principles of virtue. And though we should allow, to those who contend for it, that the *natural* arguments for a future state are not sufficient of themselves to afford full conviction of its certainty, yet when, since the promulgation of Christianity, we are convinced of it by another kind of evidence, it is not, surely, degrading Divine Revelation, to shew that its doctrines are consistent with right reason; since

* Pudsey-Ordination-Service, Q. III. p. 60.

both

both are the gift of the ſame Almighty Being, from whom contradictions cannot ariſe.

III. We are now come to the *nature* of puniſhment. Concerning the nature of thoſe puniſhments which will be inflicted by the Deity in conſequence of immoral actions, it is impoſſible for us to determine, in what they differ from human puniſhments, and how far they extend. Only we may conjecture, that, as the moral government of the Deity is of a ſpiritual or mental nature, the puniſhments alſo will probably be mental; and may poſſibly exiſt as long as their ſubject, the mind. Human governments, on the other hand, being entirely of a temporary nature, the puniſhments they provide muſt be temporary alſo; ſuch as may either *produce an amendment in the offender himſelf*, by laying before him ſuch motives as may be ſufficient to deter him from a repetition of his crime, or place him in ſuch a ſituation, as ſhall take away from him all opportunity of doing further miſchief. The firſt of theſe claſſes comprehends *fines*, *corporal puniſhments*, *impriſonment for a limited time*, and *temporary baniſhment*; the ſecond claſs includes *perpetual impriſonment*, or *exile*, and *death*.

It is obvious that theſe ſanctions carry with them different degrees of ſeverity: which leads us to enquire into.

IV. The *rule* or *meaſure* of puniſhment.

The general rule of all puniſhments is, that the

the feverity be proportioned to the enormity of the crime. But the difference between ethical and political virtue (if fuch an expreffion may be allowed) is no where more apparent, than in this article. The term enormity, when applied to crimes committed againft the laws of morality, fignifies the *moral depravity* of the action, which is diminifhed by any temptations there may be to commit it; fince, as it requires greater fortitude to refrain from the commiffion of a crime, when it is recommended by numberlefs temptations, fo thefe furnifh an apology for the perfon, who has been fo unfortunate as to yield to them. The *frequency* of the crime, particularly, operating as a temptation, furnifhes an efpecial excufe for its commiffion. And in like manner, all other circumftances, which may tend to induce a man to commit any given offence, act like negative quantities in arithmetic, tending to diminifh the fum of enormity, and confequently to leffen the punifhment.

But when any actions are confidered as offences againft human laws, the term enormity is not ufed in a moral fenfe, but fignifies *the degree of detriment any particular action may occafion to the ftate.* And, by this rule, actions, in themfelves of little or no moral turpitude, may be punifhed with the greateft feverity, as is frequently the cafe with the crime of high treafon; while, on the other hand, the vileft and moft complicated

acts

acts of villainy, may, through a necessary defect of foresight in the legislator, not only pass unpunished, but even, in some cases, be rewarded. I am enabled to produce a case, which will greatly illustrate what has been said: it comes from an authority, which will readily be acknowledged to be unquestionable.* In one of the midland counties of England, not many years ago, an unnatural son hired a bravo to murder his father. In consequence of the old man's death, a proclamation was issued out, offering a reward to any one who would discover the offender, and a pardon to any accomplice *who was not the immediate murderer.* The son informed against the person whom he had himself hired, and, upon his conviction and execution, claimed and obtained the pardon and the reward. Now we cannot, if we wished it, conceive a more glaring instance of moral depravity; and yet, by human laws properly constituted, this most atrocious of all persons was not only indemnified, but rewarded, for that very action, in which his villainy was most eminently apparent.

In this view of the term, the *frequency* of any crime increases, instead of lessening, its enormity.

* Dr. Aikin (a man never to be mentioned by his pupils but with gratitude and veneration) produced this instance in his Ethical Lectures, as a case which happened in Leicestershire, during his residence at Kibworth.

For

For all crimes being hurtful to the ſtate, their frequent commiſſion ought to be carefully prevented, and the increaſe of them is an alarming ſymptom of political decline. When, therefore, any crime is often repeated, its puniſhment muſt increaſe accordingly, in order to counterbalance the additional temptation, which its general commiſſion might otherwiſe occaſion. Thus in the year 1748, his late Majeſty iſſued a proclamation, ſetting forth, that in conſequence of the great frequency of high-way and ſtreet-robberies, he would pardon no perſon convicted of this crime for the ſpace of a year to come; which was, in effect, an increaſe of puniſhment, as it took away the chance of eſcaping. *

For the ſame reaſon, all other temptations to the commiſſion of crimes, are to be counterbalanced by ſuch additional puniſhments, as may furniſh ſufficient motives to refrain from them. Among theſe temptations, *difficulty of detection* is one of the moſt powerful, † and is on that account moſt generally and ſtrictly guarded againſt. Thus, in cloathing countries, to cut off, and take away a *part* of a piece from the tenter-hooks is a *capital* offence; but to ſteal the *whole* piece only ſubjects the delinquent to

* A ſimilar meaſure was purſued, in the year 1783, with reſpect to robberies attended with murder, or cruel uſage.

† See the note on footpads, page 323.

the

the puniſhment of *tranſportation.* The reaſon of this is, that if the whole piece be taken, it may eaſily be known by the marks of the maker, but if the piece be cut, the marks are loſt, and the theft cannot be ſo eaſily diſcovered. And this principle was formerly carried ſo far in the Iſle of Man, as Judge Blackſtone informs us, * that " ſtealing a horſe or a cow was only " proſecuted as a treſpaſs, on account of the " difficulty of conveying them out of the iſland, or " of ſecreting them in that ſmall territory ; while " ſtealing a pig or a fowl was made a capital " crime, as ſo ſmall an animal might eaſily " be devoured or concealed." This laſt inſtance is adduced, only to ſhew how far a principle which is good, when moderately applied, may be ſtretched into abſurd ſeverity.

Thus we ſee, that whereas the frequency of any crime, and the other temptations to its commiſſion, *leſſen* its *moral* enormity, and conſequently diminiſh its puniſhment ; theſe circumſtances, on the other hand, *increaſe* the *political* enormity of an offence, and conſequently increaſe the puniſhment alſo.

At the ſame time, it muſt be acknowledged, to be a very difficult part of the province of the human law-giver, ſo to *proportion puniſhments* to *offences*, as to keep clear, on the one hand, of

* Comm. Book IV. C. 1.

the

the inconveniences, of too *lax* a fanction to the laws, and to avoid, on the other, the evils of too *fevere* a one.—In order to do this with exactnefs, it is requifite that there be previoufly obtained a full and perfect fcale* of offences, claffed according to their *political enormity*, † which perhaps is impoffible; and we muft afterwards be able to apply the feveral kinds of punifhment which it is in the power of the civil magiftrate to inflict, ‡ in a due proportion to the *degrees* of enormity marked down in the fcale. He who approaches neareft to this ideal perfection, is the wifeft and moft perfect legiflator: he who falls fhort of it, muft, in that degree, labour under great difadvantages.

For if the *evil confequences* of the punifhment he appoints be lefs than the *probable advantages* of the crime it is meant to reftrain, it will, in effect, be worfe than no punifhment at all; for then, what is gained by the crime, is gained not only fecurely, but *legally*. The article of fmuggling will afford us a ftriking example. The *political enormity* of this offence feems not to have been fufficiently attended to. ‖ It ought to be remembered, that other offences, without the

* Beccaria, C. VI. † See above, I. 4.

‡ See above, I. 3.

‖ Except by Dr. Franklin. See his admirable paper on fmuggling in his Mifcellaneous Pieces.

exception even of murder, *immediately* affect *individuals* only; whereas, in this caſe, an immediate, open, and violent attack is made upon the property of the whole community, by endeavouring to defraud the ſtate of thoſe duties, which make a part of its juſt revenues. One ſhould therefore expect, that even the ſevereſt puniſhment would be provided againſt a crime, of this nature: whereas we find, that all the ill conſequence that generally ariſes to the offender, is the ſeizure of thoſe goods, the duty upon which he thus illegally avoids the payment of;* and, in ſome caſes, a ſmall pecuniary fine. Now if it be a chance of ſix, or ten to one, that ſuch a ſeizure will not be made, is this ſufficient to *deter*, nay is it not enough to *encourage* the ſmuggler

* This Judge Blackſtone aſſerts (I. p. 317.) is the only natural and reaſonable puniſhment for ſmuggling; but at the ſame time laments its inefficacy, and the neceſſity of greater ſeverity, in order to the reſtraint of a crime, "which, ſays he, is no natural, but merely a poſitive offence." But if this were a ſufficient reaſon for lenity in the caſe of *ſmuggling*, it would be ſo likewiſe for *high-treaſon*. This admirable writer ſeems not to have attended to the diſtinction between moral and political enormity.

If it be objected, that all *forcible* acts of ſmuggling, reſiſtance to cuſtom-houſe officers, &c. are declared by 19th Geo. II. C. 34. to be *felony*, it may be replied, that other crimes are here involved with ſmuggling; of which *ſhooting at*, or *murdering*, any one, is felony by itſelf; and reſiſtance to the officers appointed to execute the laws, is a kind of treaſon. So that it is not ſmuggling, but *murder* and *treaſon*, that are puniſhed by this ſtatute.

gler

gler to perſiſt in, a practice ſo highly detrimental to ſociety?

If, on the contrary, the puniſhment be too ſevere, as is the caſe, at leaſt, whenever it is more than adequate to the prevention of the crime, the following pernicious conſequences muſt neceſſarily enſue.

1. As human puniſhments cannot riſe beyond a certain height, if the ſeverer ones begin to be inflicted too low in the ſcale of offences, the higheſt puniſhments will be brought into uſe long before we reach the higheſt offence; the neceſſary conſequence of which muſt be, that crimes of different degrees of enormity will be puniſhed equally. From hence it will as neceſſarily follow, that ſuch crimes will be looked upon as indifferent with reſpect to each other. Habitual offenders are accuſtomed to eſtimate crimes by their conſequences, and not by their moral turpitude: whenever, therefore, the civil magiſtrate makes no difference between the *puniſhment*, they will be apt to make as little difference between the *commiſſion*, of one, two, or more of them; according as it may ſuit their preſent convenience, or occaſion leſs danger of detection.* Thus, if both robbery and murder

* Can there be a better reaſon given, why footpads more frequently accompany their depredations with cruelty than highwaymen on horſeback, than that, as they are more eaſily purſued, it is their buſineſs to render the ſufferers incapable of purſuit?

are punished equally, the highwayman will naturally argue with himself thus: "I shall be liable "to the same punishment whether I rob this man, "or whether I rob and murder him too; but "if I rob him only, I leave an informer, who "will endeavour to bring me to justice; my "safest way, therefore, is to put an end to him "at once, and so place an effectual bar to all "information, at least from that quarter." This is the reason which Judge Blackstone assigns, though there may probably be others, why in France they seldom rob but they murder also, whereas in China, where murderers only are cut to pieces, they often rob, but never murder.* And he at the same time answers the question "why does not this principle operate "in England, as well as in other countries?" by shewing, that though the same punishment is provided both for robbery and murder, yet the robber has many chances of escaping, while the murderer is almost sure of having his sentence strictly executed: besides that a difference is made, both in the expedition and solemnity of the execution, and in the subsequent disposal of the body.

2. Again, if the same punishment must serve for different crimes, and the highest punishment is an adequate satisfaction for the highest crime,

* Comm. B. IV. C. 1. p. 18.

for

for many crimes it must be *more* than a satisfaction, and therefore worse, that is, more detrimental to society, than the crime itself. The laws of Draco, we are told, were made on a different principle: he conceived *that the least offences merited death*, and he could find no greater punishment for the highest. But however those divines may determine on this subject, who contend, *that every sin, being an offence against an infinite being, is deserving of an infinite and eternal punishment*,* yet certainly no politician will admit this lawgiver's principle. And we need not wonder that his dreadful code, emphatically, but properly said to have been *written in blood*, was not suffered to continue long in force.

But this evil is of still greater consequence, as it leads to another of much more fatal tendency. For,

3. The too great severity of punishments *hinders the execution of the laws*, especially of those which have for their object crimes of a less atrocious nature. In this case, † either the party injured is induced to neglect a prosecution, rather than cause the delinquents to be so heavily punished; or, if he brought to a trial, the jury

* Is it not at least as plausible to say, that every sin, being the action of a *finite* being, may be corrected by, and therefore is only deserving of, a finite and temporary punishment?

† Blackstone, B. IV. C. 1. p. 19.

are led to violate their oath, and perjure themſelves to procure his acquittal; and if all this is not ſufficient to ſave him, the judge contrives to avail himſelf of ſome palliative circumſtance which may juſtify a reſpite: ſo that it is a pretty certain fact, that of all the criminals convicted in England upon capital indictments, ſcarcely one in three really ſuffers the puniſhment appointed by the laws.* Now it is wiſely obſerved by one who well underſtood human nature, † and the obſervation is confirmed by conſtant experience, that crimes are more effectually prevented by the *certainty*, than by the *ſeverity*, of their puniſhment. For ‡ every offender, when he reflects upon the very ſmall proportion of convicts that really ſuffer for their offences, naturally encourages himſelf with the reflection. "Why ſhould not I eſcape as well as others?"—And if, contrary to

* See the *table of executions* at the end of Howard on Priſons.

† Beccaria. C. VII.

‡ Blackſtone has expreſſed this ſentiment ſo much better, that I cannot reſiſt the temptation to copy his words:

"Among ſo many chances of eſcaping, the needy and "hardened offender overlooks the multitude that ſuffer; "he boldly engages in ſome deſperate attempt, to relieve "his wants or ſupply his vices; and if, unexpectedly, the "hand of juſtice overtakes him, he deems himſelf peculiarly unfortunate, in falling at laſt a ſacrifice to thoſe "laws, which long impunity has taught him to contemn." Vol. IV. p. 19.

his

his own expectations, and to general probability, the punifhment fhould, in the end, fall upon him, he does not fo much confider it as the juft recompence of his crimes, as lament his misfortune, it being marked out as the victim of an unjuft and unreafonably fevere inftitution.

Further, the feverity of punifhment *retards* its execution, even in the cafe of thofe who actually fuffer.

Nulla unquam de *morte* hominis cunctatio longa eft,

is a wife fentiment of the poet, * which may be extended to *all* fevere inftitutions, and ought to have its due influence, as long as they continue in force: though, if it were merely on this account, all fuch inftitutions ftand greatly in need of a reform. For the minds of the common people cannot eafily, at fuch a diftance of time, connect the punifhment with the action that has occafioned it, and are tempted to confider an execution, when it takes place long after the offence committed by the fufferer, rather in the light of a cruel and terrible exhibition, than as the juft confequence of a particular violation of the laws of fociety. †

Thefe obfervations are intended to have a particular reference to capital punifhments, which, however defended by fome politicians, appear

* Juvenal.

† Blackftone, B. IV. C. 31. Vol. IV. p. 397.

to have been oppofed of late by all the moft refpectable writers on government; * and indeed are certainly in moft cafes, if not univerfally, abfurd and impolitic.

Every wife and benevolent man will confider with himfelf, that as life is a bleffing which he cannot give, fo it behoves him carefully to examine his right to take it away. He will confider, that when mankind entered into fociety, they only gave up fuch a portion of their natural liberty, and fubmitted to only fuch a meafure of reftraint, as was effentially neceffary to fecure to its members the *advantages* of fociety; and, therefore, that if this important end can be anfwered without having recourfe to the punifhment of death, there is no right belonging to the magiftrate of inflicting fuch a punifhment.†

* Sir Thomas More, Grotius, La Coke, Beccaria, Montefquieu, Blackftone, Voltaire.

† This feems to be a better argument than the excellent Marq. Beccaria's upon the fubject, viz, "that no man "has a right to take away his own life in a ftate of nature, "and therefore cannot give up any fuch right to the magi-"ftrate." (And Confiderations on Crim. Law. p. 186.) For, admitting that no man has fuch a right, it muft be obferved, that his *right over himfelf*, in a ftate of nature, is not what he gives up, but his *right over others*, when he enters into fociety. And it will bear a difpute, whether a man, entirely free from controul, has not a right to eftimate his lofs by an injury, at what value he pleafes.

Now

Now that, ſo far from being neceſſary to anſwer this end, capital puniſhments are exceedingly impolitic, and, as far as they operate, tend frequently to prevent it, the obſervations already made *on ſevere puniſhments in general* might be ſufficient to ſhew.

But to theſe we may add, further, that the uſe of capital puniſhments argues a want of capacity in the legiſlator. It is rather an *expedient to get rid of* certain inconveniences in ſociety, than an *attempt to remedy* them. It is eaſy enough, indeed, for the magiſtrate to *extirpate* mankind, but it is his buſineſs to amend them, and make them happy. "It is *quackery* in government," ſays Blackſtone, "to apply too frequently the "ſame univerſal remedy, the *ultimum ſupplicium*: "and that magiſtrate muſt be eſteemed both a "weak and a cruel ſurgeon, who cuts off every "limb, which, through ignorance or indolence, "he will not attempt to cure." *

The idea of capital puniſhments would naturally ſuggeſt itſelf in the infancy of a ſtate. When any one had committed an offence, and diſturbed the peace of ſociety, the queſtion would then firſt ariſe "How ſhall we prevent theſe things?" And the anſwer moſt likely to occur to a ſet of barbarians would be, "Extirpate the offender, "and give yourſelves no further trouble about

* Blackſtone, B. IV. C. 1. p. 17, 18.

" him."* But, as civilization increaſed, it would ſoon be found a wiſer method, to provide ſuch expedients as might effectually induce the offender himſelf not to repeat his offence, deter others from its future commiſſion, and, at the ſame time, preſerve an uſeful member to ſociety. And though I will not undertake to determine univerſally, that in proportion as political governments have advanced towards perfection, ſubſtitutes for capital puniſhments have been more frequently introduced; † yet I think it may be

* So the Hottentots have no fixed laws to direct them in the diſtribution of juſtice, and conſequently, when any offence has been committed, there is no form of trial, or proportion of puniſhments to offences; but the *Kraul* (village) is called together, the delinquent is placed in the midſt, and without further ceremony, demoliſhed with their clubs, the chief ſtriking the firſt blow.

† Feudal times will furniſh us with a ſtriking exception. Every one will acknowledge the imperfection of this form of government; and yet, under it, almoſt all crimes were reſtrained (or more properly *licenſed)* by pecuniary mulcts: and few *capital* puniſhments were in uſe, except, moſt abſurdly, for breaches of the foreſt law. The legiſlators of thoſe days ſeem injudiciouſly to have followed, in regulating a ſociety of which they were *properly* the governors, the example of that cotemporary hierarchy, which ſucceeded in its attempts to perſuade mankind, that it could controul the diſtribution of puniſhments under a conſtitution of government, of which *its* chief directors were likely to be ranked among the moſt unworthy members.

be asserted with perfect safety, that government will never arrive at the perfection of which it is capable, till some very essential reform is obtained in our treatment of criminals.

And as frequent capital punishment is an argument of the want of a regular police, and a relique of barbarism in the constitution of any society, so its being still obstinately continued in use among us tends to retain among the common people those barbarous manners, from which this kind of punishment originally took its rise, and to check the progress of that humanity of spirit, which, happily for mankind, has of late been making such rapid advances in our part of the world. Let then the spirit of our punishments correspond with the spirit of the times, in order that we may sooner attain that perfection of universal charity, which ought to be the governing principle of the human mind.

Indeed the advocates for capital punishments seem now in general to be aware of the weakness

As *these* held forth a regular bill of indemnity for *sins*, with prices proportioned to their enormity; so *those* published a similar list of prices for licence to commit *crimes*: and whereas, *spiritually*, you might blaspheme against the Almighty for a trifle; so, *politically*, for a stated price, you might purchase the life of the king. A curious constitution, it must be confessed, where the *supreme magistrate* might be murdered with *safety*; but where it was *death* to shoot a *partridge*!

of

of their ground, and at prefent feldom attempt to maintain it, except in cafes of murder and high treafon. Perhaps in the latter cafe it may, fometimes, be neceffary: and in the former, fcripture is brought in upon us, and requires, it is afferted, the rigorous infliction of death. Now with refpect to the inftitutions of Mofes, it is to be confidered, that they were made for the regulation of a very peculiar people, for very particular purpofes. Their whole civil conftitution feems to have been admirably adapted to the progrefs then made in political advancement; but to have been at the fame time fo contrived, as to keep them where they were, till the opening of a more perfect difpenfation. All, therefore, that we can fairly conclude from the inftances of capital punifhments, prefcribed by the law of Mofes, feems to be, that fuch punifhments are not, in their own nature, abfolutely and univerfally, unjuftifiable; for the God of nature, we may be affured, would never contradict and overthrow the eftablifhed *laws* of nature. But I can no more conceive that we are obliged, in this inftance, to copy the Jewifh code, than that we ought to have retained the law of retaliation, * or that we are wrong in not adopting the whole fcheme, without alteration, referve, or addition.

* Ex. xxi. 24. Lev. xxiv. 20.

But

But the puniſhment of murder by death, it is ſaid, does not appear to have deduced its origin or obligation from the law of Moſes alone, but to have been required by the precept given to Noah and his poſterity, * "Whoſo "ſheddeth man's blood, by man ſhall his blood "be ſhed," and conſequently to be obligatory upon all the deſcendants of that patriarch. I hope I ſhall not offend any one, by taking the liberty to put my own ſenſe upon this celebrated paſſage; and to enquire, why it ſhould be deemed a precept at all. To me, I muſt confeſs, it appears to contain nothing more than a declaration of what will generally happen; and in this view, to ſtand upon exactly the ſame ground with ſuch paſſages as the following. † "He that leadeth into captivity ſhall go into "captivity: "He that taketh up the ſword "ſhall periſh by the ſword." The form of expreſſion is preciſely the ſame in each of theſe texts; why then may they not be all interpreted in the ſame manner, and conſidered, not as commands, but as denunciations? And if ſo, the magiſtrate will be no more *bound* by the text in Geneſis, to puniſh murder with death, than he will, by the text in the Revelations, to ſell every Guinea captain to our Weſt India planters.

* Gen. ix. 6.

† Rev. xv. 10. Matt. xxvi. 52.

And,

And yet, however just and proper such a proceeding might be, I suppose no one will assert, that the magistrate is *bound* to it by either that or any other text in the scriptures; or that *that alone* would be admitted, as a *sufficient reason* for so extraordinary a measure. *

But in considering the punishment of murder by death, upon the footing of *political advantage*, which alone has any thing to do with the question, may it not justly be asked, what natural reason can be given, why the loss of one member of society should necessarily be followed by the loss of another! And, if none *can* be given, whether the present practice, on such occasions, is any thing more, than a barbarous expedient to get rid of a difficulty, than hastily *cutting* a knot, because a little dexterity is requisite to *untie* it?

It would surely better become a wise politician, to enquire, what are the springs which lead men to the commission of crimes; and so to suit his punishments to particular offences, as that they shall in their own nature tend to prevent them, and correct their evil influence; and not to inflict random punishments, merely to make the delinquent suffer.

* Let it also be observed, *by those who will quote scripture upon the occasion*, that when Cain murdered Abel, God only *set a mark* upon him, that is, rendered him infamous. This is a scripture *precedent!*

Now

Now it will not be difficult to fhew, that the principal fprings of evil actions are, *pride, luxury*, and *idlenefs*, affifted by the influence of *bad examples.* To correct the ill effects of thefe things, we at prefent confine our prifoners in a ftate of *abfolute indolence*, in the company of the *moft deteftable* of their fpecies, who *encourage*, inftead of *fhaming* them, *with free accefs to the means of intemperance*, the goaler being generally a publican, and after five or fix months of *this kind of difcipline*, we *whip*, *banifh*, or *hang* them. In other words, we *cherifh*, as much as we are able, thofe *principles*, and *confirm*, beyond the poffibility of amendment, *thofe habits*, which are the *foundations of all vicious conduct*; and then inflict upon them a momentary punifhment, which, if they furvive, they return into fociety prepared *by ourfelves* to become its moft deteftable members; and if their punifhment be the conclufion of their prefent exiftence, we have been *doing them an injury which we cannot repair*, by contriving for the laft months of their lives fuch a courfe of conduct, as was fure to confirm their vicious principles and habits.

Is all this rational and wife? Does it manifeft found judgment, or good policy? Surely not. Right reafon would fuggeft a very oppofite proceeding. To counteract the effects of idlenefs and luxury, and prevent the influence of bad company, it would fhew, that it was much

much more eligible, to apply the punifhments of *fhame*, *hard labour*, * *coarfe diet*, and *folitary confinement*; and thefe in different degrees, according to the different enormity of the offences committed, and in proportion as they have arifen from one or another of thefe caufes.

Many advantages feem likely to arife from this mode of punifhment. That the *certain* infliction of *hard labour* would have more influence upon the mind of the offender, than the prefent *bare probability* of death, may naturally be fuppofed, and indeed has been frequently experienced. And the duration of the punifhment would make a much deeper impreffion upon fpectators, than the *inftantaneous execution* of a criminal, and would therefore tend to deter more effectually from the commiffion of crimes in future. In fuffering this kind of punifhment alfo, the offender is compelled, in fome degree at leaft, to fupport himfelf by his own labour, as long as he remains under confinement; he will alfo form habits of temperance and induftry, and thus be prepared for ufefulnefs in the world, when the term of his punifhment is elapfed. And that the reformation of the offender will be very much promoted by fome portion of

* Diodorus Siculus tells us, that Sabaco, king of Egypt, changed capital punifhments, with much fuccefs, into ftated kinds of labour. Whofe example Grotius recommends.

folitary

solitary confinement (affording him opportunities of reflection, breaking him from the society of his old companions, &c.) has been sufficiently shewn by the excellent Mr. Howard, in his *State of the Prisons in Holland.* *

But the best method, where it can be done, of amending our penal code, is to take away all occasion for its severe institutions, by preventing, as much as possible, the crimes they restrain from being committed; or in other words, by having recourse to such previous expedients, † as shall remove every prospect of advantage from their commission. Thus, while no other precautions were used to prevent the *coining of gold*, than the making it a capital crime, the offence grew every day more frequent; but, as soon as the late regulations respecting gold coin took place, which entirely preclude every

* See particularly his story of the *shoe-maker*, who always drank the health of his friends, the masters of the Rasp-house, for teaching him sobriety and industry.

† Laws which only take effect *à posteriori*, and propose the prevention of crimes by cutting off the delinquent, will never reform; whereas prudent provisions to correct the morals, and proper punishments to counteract the principles of criminality, will have sure and lasting effects. Without such provisions, we may be making perpetual alterations, but shall in vain expect any salutary effects; we shall resemble those patients who are always taking physic, but will not alter their bad diet, and intemperate modes of living. Crim. Law, p. XIX.

prospect,

proſpect of advantage from this practice, the offence died away of itſelf; and we now ſcarcely ever (I believe I may ſay *never)* hear of a ſingle offender in this reſpect.

Theſe are the expedients which have hitherto been uſed in thoſe countries, where attempts have been made to ſubſtitute other puniſhments in the room of capital ones, and otherwiſe to reform the penal inſtitutions; and they have, I believe, been almoſt univerſally attended with ſucceſs. The governments of China, Ruſſia, * and Pruſſia have been foremoſt in theſe experiments, while other, perhaps more perfect, ſtates, have not purſued this laudable meaſure ſo far as might have been expected. Even in England, this excellent work has not hitherto been entered upon with proper ſpirit. Our penal laws have too frequently been the work of a few, influenced by various improper paſſions, and not directed by that coolneſs which legiſlators ought always to poſſeſs. They have too often been made *upon the ſpur of the occaſion,* as Lord Bacon expreſſes it, and when ſo made, their reviſal has been afterwards neglected; † or we ſhould

* Grand inſtructions for forming a code for the Ruſſian Empire. § 210.

† If Lord Aſhburton really was engaged, as we were told, in the reviſal, amendment and digeſtion of our code of penal laws, his death is much to be lamented by every friend to humanity.

not,

not, in the eighteenth century, * have had reaſon to acknowledge with ſhame, that ſtealing a ſwan, [1] breaking down a cherry tree, [2] letting out the water of a fiſh pond, [3] being ſeen in the company of gypſies, [4] with upwards of a hundred and fifty other actions which a man is daily liable to commit, [5] are declared, by Engliſh Acts of Parliament, *crimes worthy of inſtant death!*

Is not this a fact at which Engliſhmen ſhould bluſh? And ought not our legiſlators to undertake, without delay, the great but neceſſary work of reforming theſe ſanguinary and impolitic ſtatutes? Our country glorioufly led the way in the abolition of torture; let us not be aſhamed to follow the good example which others have ſet us in return, and ſtill further

* Blackſtone. vol. IV. p. 4.

[1] Dalt. Juſt. C. CLVI.

[2] 31ſt Geo. II. C. XLII.

[3] 9th Geo. I. C. XXII.

[4] 5th Eliz. C. XX.

[5] Ruffhead's Index to Statutes.

After this, will not any one acknowledge that Judge Forſter, in the preface to his Crown Law, recommends its ſtudy with ſingular propriety, as a matter of univerſal concernment? "For," ſays he, "no rank or elevation "in life, *no uprightneſs of heart*, no *prudence* or *circumſpection* "of *conduct*, ſhould tempt a man to conclude, that he "may not, at ſome time or other, be deeply intereſted "in it."

humanize

humanize our civil inftitutions. We fhall then have performed a work for which pofterity will regard us with gratitude; and our age will then ftand a chance of ftill acquiring the fame reputation for humanity and public fpirit, which it juftly merits for the encouragement it affords to improvements in the arts and fciences.

To conclude; It has been the object of this difcourfe to prove,

That the *end* of all punifhments is, not to torment a fenfible Being, but to prevent the future commiffion of crimes;

That thofe only can be deemed proper *fubjects* of human punifhments, who have been proved guilty of offences againft the peace and good order of fociety;

That the *political enormity* of offences, or that which fixes the proportion of their punifhment, is to be eftimated by the degree of detriment they occafion to the ftate;

That the *nature* of all punifhments fhould be fo fuited to their refpective offences, as that they fhall naturally tend to prevent their future commiffion, by correcting the principles which gave rife to them:

That the magiftrate has no right to inflict punifhments *unneceffarily fevere*;

That he ought to be very fparing (if he have recourfe to them at all) in the ufe of *capital punifhments*;

And

And that in every inſtance he ought to appoint only ſuch ſanctions to his laws, as ſhall be *adequate*, and *no more than adequate*, to prevent *the crimes which* are the objects of them.

If, in the courſe of this ſlight Eſſay, any thing has been offered in the leaſt degree worthy the attention of this reſpectable Society, and more eſpecially, if it ſhould be the means of furniſhing agreeable and uſeful topics of debate, its end will be anſwered, and its author ſatisfied.

Mem. The rule, "That the meaſure of puniſhment "ſhall be ſuch as may be adequate to the prevention of "the offence," muſt only be extended to ſuch offences as it is in the magiſtrate's power to prevent without occaſioning a greater evil than will ariſe from its permiſſion. Judge Blackſtone happily obſerves, "The damage "done to our *public roads* by loaded waggons is univer-"ſally acknowledged, and many laws have been made "to prevent it, none of which have proved effectual." *But it does not therefore follow that it would be juſt in the legiſlature to inflict death* upon every obſtinate carrier who defeats or eludes the proviſions of former ſtatutes. Vol. IV. p. 10.

On the PURSUITS *of* EXPERIMENTAL PHILOSOPHY. *By* THOMAS PERCIVAL, M. D. F. R. S. *and* S. A. *&c.* *Read May* 14, 1784.

Homo, naturæ miniſter et interpres, tantum facit et intelligit, quantum de naturæ ordine, re vel mente, obſervaverit; nec amplius ſcit, aut poteſt. BACON, NOV. ORGAN. APH. I.

THE very learned and ingenious author of Hermes * has ſtigmatized the purſuits of modern philoſophy, by treating them as mere *experimental amuſements*; and charging thoſe who are engaged in ſuch purſuits, with deeming nothing *demonſtration*, that is not made *ocular*. Thus, inſtead of aſcending from *ſenſe* to *intellect*, the natural progreſs of all true learning, he obſerves, that the philoſopher hurries into the midſt of ſenſe, where he wanders at random, loſt in a labyrinth of *infinite particulars*. It would be eaſy to retaliate on this celebrated writer, by pointing out the futility of the ſyllogiſtic mode of philoſophizing, inſtituted by his favourite Ariſtotle. I might alſo oppoſe to his authority, that of Lord Verulam, the brighteſt luminary of

* See a Philoſophical Enquiry concerning univerſal Grammar, by James Harris, Eſq. p. 361.

ſcience,

ſcience, who objects, in the ſtrongeſt terms, againſt that reverence for ſpeculations, purely intellectual, " by means whereof," as he expreſſes himſelf, " men have withdrawn too much " from the contemplations of nature, and the " obſervations of experience, and have tumbled " up and down in their own reaſon and conceits. " Upon theſe intellectualiſts, who are notwith- " ſtanding commonly taken for the moſt ſub- " lime and divine philoſophers, Heraclitus gave " a juſt cenſure, ſaying, *men ſought truth in their* " *own little worlds, and not in the great and common* " *world.*" *

But, without depreciating metaphyſics, a ſcience which I have always ſtudied with delight, and which invigorates the faculties of the mind, and gives preciſion and accuracy to our rational inveſtigations by inſtructing us in the nicer diſcriminations of truth and falſhood, no doubt can be entertained of the high importance and dignity of natural knowledge. To this we owe the neceſſaries, the conveniences, and all the gratifications of our being; † and in the purſuit of it the underſtanding is exerciſed and improved, and our

* Bacon on the Advancement of Learning, book I. p. 20. 4to.

† *Scientia et potentia humana in idem coincidunt.* Bacon, Nov. Org. Aph. III.

moral affections are elevated to ſuperior degrees of piety, towards the great Author of all that is fair and good in the creation. Nor is modern philoſophy liable to the charges, which have been thus contumeliouſly brought againſt it. For, I truſt, it has been conducted, on the principles of genuine *logic*, by all its more diſtinguiſhed profeſſors, who have been ſeduloufly careful firſt to eſtabliſh ſound premiſes, and then to deduce juſt concluſions.

The immortal Newton, from an appearance, which we daily obſerve, the fall of bodies to the ground, aſcended by patient inveſtigation, and by a regular gradation of evidence, to the great law of gravity. And having aſcertained this general principle, he extended it over the univerſe, explaining by it not only the phænomena of our globe, but the revolutions of the whole planetary ſyſtem. By the ſucceſſive adoption of the ſame *analytic* and *ſynthetic* mode of reaſoning, he demonſtrated his beautiful theory of light and colours. Numberleſs other ſubſequent diſcoveries have been conducted on the ſame ſcientific plan, as might be evinced by references to the writings of our own and foreign philoſophers.

Even the chemiſts have long ſince deſerted their jargon and myſterious conceits; and they now carry on their reſearches in a perſpicuous and rational manner. That unknown principle phlogiſton, to which they referred ſo many opera-

tions

tions of nature, explaining, as the logicians exprefs it, *ignotum per ignotius*, has been lately proved to be no creature of the imagination; and may be exhibited to the fenfes, under the form of inflammable air. Fire, fubtle as it is in its activity, and univerfal in its energy, has been traced through all its modifications, meafured by different ftandards, and reduced to known, precife, and permanent laws. It is therefore no juft complaint, that intelligent principles are neglected, and that empyricifm in phyfics is honoured with exclufive encouragement. Yet, in the prevailing rage for experiments, it cannot be unfeafonable to caution the young adventurer, not to deem the microfcope, the retort, or the air-pump unerring guides to truth; but to profecute his refearches into nature with a modeft conviction of the fallacy of his fenfes, and the limited powers of his underftanding. "You will wonder," fays Mr. Boyle, in the preface to his effays, "that I fhould ufe fo often "*perhaps*; *it feems*; *'tis not improbable*; words, "which argue a diffidence of the truth of the "opinions I incline to. But I have hitherto "not unfrequently found, that what pleafed me "for a while, was foon after difgraced by fome "further or new experiment."

Mr. Bewley, an eminent chemift, not long fince, informed me, that he concluded the prefence of the vitriolic acid to be unneceffary to produce

produce the ſpontaneous accenſion of Homberg's pyrophorus, and delivered this opinion to the public, on the evidence of at leaſt fifty different trials.*. Yet, with materials taken from the ſame bottle, the experiment afterwards failed nearly as often, though the minuteſt circumſtances in the proceſs were as much alike, as attention could render them. Contrarieties, equally humiliating, have often occurred in my own philoſophical purſuits But the moſt inſtructive leſſon of modeſty and reſerve, which I recollect in the courſe of my experience, is the one I ſhall now briefly recite.

The favourable influence of fixed air on vegetation I believed to have been aſcertained by more than a hundred experiments, which I made in the year 1775. Many of theſe experiments were repeated afterwards by Mr. Henry, Mr. Bew, and others. But Dr. Prieſtley, whoſe accuracy and fidelity are not leſs diſtinguiſhed than his learning and ingenuity, has ſince drawn concluſions from the proſecution of this ſubject, which militate totally with mine. I reſumed the enquiry, and engaged ſeveral of my friends in it. The reſult of all our trials was uniformly the ſame as before, viz. that fixed air, in a due proportion, is ſo favourable to vegetable growth,

* See Prieſtley on Air, vol. III. Appendix, p. 395.

that

that it may justly be deemed a pabulum of plants. Dr. Priestley's subsequent experiments, however, were still contradictory to mine: And in one of his very friendly letters to me, he thus expresses himself. "In all these cases, "you will say, I choak the plants with too "great a quantity of *wholesome* nourishment: "And to all yours I say, you do not give them "enough of the *noxious matter* to kill them. "Thus the amicable controversy must rest be-"tween us; and like all other combatants, we "shall both sing TE DEUM." But I felt little disposition to exultation on such an occasion, and dropt the subject, conscious that though nature is always the same, we often view her under fallacious appearances. Time, however, and the researches of foreign philosophers have thrown new lights on this disputed point. And I am informed, by a letter from our common friend, Mr. Vaughan, that Dr. Priestley now admits the salubrity of fixed air to vegetable life. I shall copy the paragraph, which contains the account. "Dr. Priestley tells me "of a very valuable book, written by a person "at Geneva, on vegetation; particularly as to "the influence of light, which he maintains to "be a phlogisticating process, acting on the "resinous parts of plants only. He also "affirms, to the satisfaction of Dr. Priestley, "that not only phlogiston is the grand pabulum "of

" of plants, but that its predominant form " of reception is that of fixed air; which, in a " proper degree and place of application, he " ſhews to be ſalutary to all plants whatever."

Differences in the reſults of our enquiries, or in thoſe of others, whilſt they incite attention, and guard us againſt confidence and preſumption, ſhould neither diminiſh the veneration due to philoſophy, nor repreſs our temperate ardour in the purſuit of truth. We ſhould recollect that though the operations of nature are ſimple, uniform, and regular, they are only diſcovered to be ſuch, when fully unfolded to our underſtandings. And that, when we endeavour to trace her laws, by artificial arrangements, combinations, or decompoſitions, which is all that *experiment* can accompliſh, * ſucceſs may be ſometimes fruſtrated by circumſtances ſo minute, as to elude the moſt ſagacious obſervation. From the hiſtory of electricity it appears, that the gentlemen, firſt engaged in the culture of that ſcience, aſcribed oppoſite effects to the uſe of boiling water in the Leyden phial. M. Jalabert, of Geneva, and others invariably found, that the electric powers of the bottle were increaſed by the water; whereas Meſſrs. Kinnerſley, Nollet, and Watſon, experienced the reverſe, in all their trials. It has

* Ad opera nil aliud poteſt Homo, quam ut corpora naturalia admoveat, et amoveat; reliqua natura ipſa intus tranſigit. Bacon. Nov. Organ.

ſince

since been shewn that the jarring decisions of those learned men, were owing to the difference in the action of boiling water on the several kinds of glass employed. Contradictory opinions are now held, by two very celebrated chemists, concerning the nature of steel; one asserting that its phlogiston is augmented, the other that it is diminished, in the process by which it is made. Both appeal to experiment in support of their opinions; and as the point in dispute is of importance to the arts, it merits a more compleat and satisfactory investigation.

To these examples I shall add another, in which I have myself been particularly interested. The Rev. Dr. Hales, whose experimental inquiries were generally directed to the good of his fellow-creatures, discovered a lithontriptic power, in certain fermenting mixtures. But he acknowledges the impracticability of injecting such mixtures into the bladder, with sufficient frequency, to dissolve the stone; and recites his experiments chiefly with a view to engage others in the same laudable and important pursuit. The subject however sunk into oblivion, and no further attempts of this kind were made, till the notice of the public was again excited towards the properties and uses of factitious air, by the writings of various learned and ingenious men. At this time (1774) Dr. Saunders, a physician in London, eminent for his knowledge of chemistry,

miſtry, renewed the experiments which Dr. Hales had begun, and found that the ſolvent power, aſcribed to the fermenting mixtures, reſided only in the fixed air: Hearing ſome very imperfect accounts of this diſcovery, curioſity and humanity engaged me in the purſuit of it. I recollected that Dr. Black and Mr. Cavendiſh had proved the ſolubility of various earthly bodies in water, either by abſtracting from, or ſuperadding to the fixed air, which they contain. And as the human calculus is diſſolved in the former way, by lime water and the cauſtic alkali, it appeared to me highly probable, that the effect would be produced, in the ſame ſubſtance, by the latter mode of operation. Analogy ſeemed favourable to the hypotheſis, and a ſeries of experiments, which I made with great care, in the fulleſt manner confirmed it. Two years afterwards, Dr. Falconer engaged in the ſame enquiry; and the reſults of his trials exactly coincide with thoſe which I have related. This united evidence has been alſo ſtrengthened by the ſubſequent teſtimony of Dr. Prieſtley and Dr. Hulme. Yet deciſive as it appears to be, a friend of mine, who is a very able and accurate experimenter, aſſures me, that the *calculi*, which he has tried, uniformly reſiſt the action of mephitic water. And he further adds, that not one of them has been found to contain a ſingle grain of abſorbent earth; but that all of them proved inflam-

inflammable, like gall-ftones. Dr. Heberden has, alfo, favoured me with fimilar information, refpecting their analyfis. On the other hand, I have fully fhewn, that thefe fubftances vary in their ftructure and compofition; that calcination converts fome into quicklime; that others are confumed entirely in the fire; and that a third fort yield, after burning, an infipid refiduum, incapable of giving any impregnation to water.* What then are we to infer from premifes, apparently fo inconfiftent? Let us deduce from them thefe falutary leffons; that dogmatifm is unbecoming a philofopher; that fallacy may attend our cleareft views; and that unperceived diverfities, in the fubjects of our inveftigation, may render truth compatible with contrariety of evidence.

An eagernefs to eftablifh fyftems, and a faftidious difdain of perplexity, contradiction, or difappointment, are difpofitions highly unfavourable to phyfical inveftigation. Lord Bacon has well obferved, "that one, who begins with certain-"ties, fhall end in doubts; but if he will be "content to begin with doubts, he fhall end in "certainties." † The progrefs of fcience is ufually flow and gradual; and in all ordinary cafes, the *race is not to the fwift,* but to the fteady, the patient, and the perfevering. A man of lively

* Philofoph. Medic. and Experim. Effays, vol. III. p. 161.

† Advancement of Learning. Book I. p. 20.

parts,

parts, and fertile imagination, generally engages in philoſophical reſearches, with too much impetuoſity; and if he be fortunate in the attainment of a few leading facts, he ſupplies all remaining deficiencies by conjecture and hypotheſis. But ſhould his career be obſtructed by contradictory phænomena, he quits the ſtudy of nature with diſguſt; and concludes that all is uncertainty, becauſe he has had the mortification to find himſelf miſtaken. A ſcepticiſm like this, founded in pride and indolence, is equally ſubverſive both of ſpeculation and of action. We can apply to no branch of human learning, which is ſecure from illuſion, or exempt from controverſy; nor engage in any plan of life with undeviating judgment, and uninterrupted ſucceſs. So true is the ſentiment of the Roman poet.

Nunquam quiſquam ita bene ſubducta ratione ad vitam fuit,
Quin res, ætas, uſus, ſemper aliquid apportet novi;
Aliquid admoneat: ut illa, quæ te ſcire credas, neſcias,
Et quæ tibi putaris prima in experiundo repudies.

TERENT.

But as diſappointments in life often furniſh the beſt leſſons of wiſdom, ſo thoſe in philoſophy may, frequently, be applied to the promotion of ſcience. In experimental purſuits, which are not undertaken at random, but with conſiſtent and rational views, we neceſſarily form a preconception of the induction to be eſtabliſhed. If the trials ſucceed, in which we are engaged, our

our end is obtained, and, for the most part, we rest satisfied. But if the proofs fail, some unexpected phænomena often occur, which awaken our attention, suggest new analogies, and excite us, perhaps, to the investigation of other propositions of more importance than the antecedent ones. The very interesting and comprehensive discoveries of Dr. Black, concerning the nature of calcareous earths, and alkaline salts, in their different states of mildness and causticity, originated from an incident of this kind. * And many similar examples might be adduced from the records of philosophy. But whether such be the fortunate event or not, a negative truth may be of as much value as a positive one; and consequently, success or disappointment may prove equally useful in experimental researches. †

To deduce the general characters of a body from one single property of it, individually considered, seems contrary to the rules of philosophizing. And the young experimenter should be cautious both of admitting, and of forming such analogies. Yet they are sometimes so strong as to force conviction even against the evidence of sense, and of general opinion. The diamond

* See Essays Physical and Literary.

† See the Author's Essays Medical and Experimental, vol. I. p. 106. edit. third.

was held by chemiſts, in the time of Sir Iſaac Newton, to be apyrous, and could not be ſuſ-ſpected, from any of its known qualities, to be of an inflammable nature. Yet this vigilant philoſopher did not heſitate to conſider it as an *unctuous coagulum*, ſolely from its poſſeſſing a very high degree of refractive power on the rays of light. For this power he found to depend chief-ly, if not wholly, on the ſulphureous parts of which bodies are compoſed. Late experiments have confirmed this opinion; and fully proved that diamonds conſiſt almoſt entirely of pure phlogiſton, ſince they are capable of being vola-tilized by heat in cloſe veſſels, of pervading the moſt ſolid porcelain crucibles, and of being con-verted into actual flame.

The accuracy of this inference is a ſtriking proof of the importance of judicious and compre-henſive analogies; and of the advantages reſult-ing from the mode of reaſoning by induction. For, to uſe the words of Sir Iſaac Newton, "though the arguing from experiments and "obſervations, by induction, is no *demonſtration* "of general concluſions, yet it is the beſt way "of arguing, which the nature of things admits "of; and may be looked upon as ſo much the "ſtronger, by how much the induction is more "general." This improved ſpecies of logic was firſt recommended and introduced into phyſics, by Lord Verulam, who, at a very early period

period of life, ſaw the futility of Ariſtotle's ſyllogiſtic ſyſtem, which, proceeding on the ſuperficial enumeration of a few particulars, riſes at once to the eſtabliſhment of univerſal propoſitions. *Duæ viæ ſunt, atque eſſe poſſunt, ad inquirendam et inveniendam veritatem. Altera a ſenſu et particularibus advolat ad axiomata maxime generalia, atque ex iis principiis, eorumque immota veritate judicat et invenit axiomata media; atque hæc via in uſu eſt. Altera à ſenſu et particularibus excitat axiomata, aſcendendo continenter et gradatim, ut ultimo loco perveniatur ad maximè generalia; quæ via vera eſt, ſed intentata.**

It is obvious that the force of this inductive method of reaſoning muſt depend on the advancement, which has been made, in the different branches of phyſics. Indeed, it preſuppoſes a ſtore of particular facts, gradually accumulated, but ſufficiently ample, and fit for reduction into their proper claſſes. Time and obſervation will be continually diminiſhing the number, and conſequently enlarging the boundaries of theſe claſſes, by diſcovering other relations between them, and pointing out the connection of phænomena, deemed, at firſt, diſtinct and independent. But it muſt be remembered that every acceſſion to knowledge renews the doubts and difficulties, that reſult from ignorance; be-

* Bacon. Nov. Organ. Lib. I. Aphor. 19.

cauſe it preſents freſh objects to our inveſtigation, and further deſiderata to our wiſhes. It is this endleſs progreſſion of ſcience, which, by gratifying curioſity with perpetual novelty, and animating ambition with proſpects of higher and higher attainments, ſometimes gives the attachment to it an aſcendancy over every other principle, ſo as to render it the *ruling paſſion* of the mind. And as this paſſion does not, like the love of virtue, temper its particular exertions, by preſerving a proper ſubordination in the powers, which it calls forth into action, the wildeſt extravagances of emotion and of conduct, have been indulged by thoſe, who ſubmit to its uncontrouled dominion. A great philoſopher has ruſhed naked, from the bath, into the ſtreets of a populous city, frantic with joy, on the ſolution of an intereſting problem. But as I have expatiated in another Eſſay, * on the folly of ſuch extravagant ardour in the purſuits of knowledge, I ſhall cloſe theſe reflections with the following lines from Milton.

- - - Apt the mind, or fancy, is to rove
Unchecked, and of her roving is no end;
'Till warn'd, or by experience taught ſhe learn,
That not to know at large of things remote
From uſe, obſcure and ſubtle, but to know

* On Inconſiſtency of Expectation in Literary Purſuits; Moral and Literary Diſſertations, page 183.

That

That which before us lies, in daily life,
Is the prime wiſdom; what is more is fume,
Or emptineſs, or fond impertinence,
And renders us in things, that moſt concern,
Unpractis'd, unprepar'd, and ſtill to ſeek.

Par. Loſt. Book VIII.

OBSERVATIONS *on the* INFLUENCE *of* FIXED AIR *on* VEGETATION; *and on the* PROBABLE CAUSE *of the* DIFFERENCE *in the* RESULTS *of* VARIOUS EXPERIMENTS *made on that* SUBJECT; *in a* LETTER *from Mr.* THOMAS HENRY, F. R. S. *to* THOMAS PERCIVAL, M. D. F. R. S. *and* S. A. *Read May* 14, 1784.

DEAR SIR,

IT is now many years ſince, from ſome experiments which you had made on the effects of fixed air, applied to the leaves and roots of plants, you, as appeared to me at that time, juſtly concluded that fixed air affords a pabulum for plants, which is equal to the ſupport of their life and vigour, for a conſiderable time. Some of theſe experiments were ſeemingly contradictory to the reſults of thoſe related by Dr. Prieſtley in his firſt volume. The doctor therefore requeſted that you or I would repeat them in veſſels con-

taining *pure* fixed air. For the doctor had found that plants, confined in *pure* fixed air, perished sooner than in common air.

I all along understood your meaning to be, not that fixed air, in a pure state, and quite stagnant, was nutritive to plants; but, that gradually applied, and in a continued stream, while the plant, at the same time is not confined from the common air, (in a manner analogous to what may probably take place in nature) plants do receive such a portion of nutriment, from the fixed air, as is sufficient for their temporary support, even when removed from every other means of receiving their food. This at least was the idea which I always entertained; and the conclusion to be drawn from this theory is, that, probably, fixed air constitutes a part of the food of plants, when growing in their proper element; such air being discharged by the different manures, which are mixed with their native soil; and this theory, if just, may lead to considerable improvements in agriculture. In the third volume of Experiments and Observations on different Kinds of Air, Dr. Priestley at the same time that he acknowledges that "he could conceive nothing more fair and decisive than your experiments," yet declares himself convinced that there must have been some fallacy in them, and he seems to think that he had detected it in two instances. The first supposed cause of error

was

was that your ſtandard plants, had not been placed in ſimilar veſſels to thoſe which had been expoſed to the fixed air; and the other, that, as your experiments were made in Nooth's machine, and as you had not aſcertained the proportion of fixed air which was contained in your veſſel, it was, probably, much ſmaller than you had imagined. *

To ſhew the probability of this opinion, he has related a number of experiments, by which he found that fixed air, in all proportions, from a ſtate of purity, to that of a mixture of $\frac{1}{8}$ fixed air to $\frac{7}{8}$ common air, was injurious to vegetation, and deſtructive to the colour of roſe leaves. Yet, with his uſual candour, he publiſhed, in the Appendix to that volume, an account of ſeveral experiments, which I had tranſmitted to him, in the latter end of the year 1776. †

By theſe it appeared that a ſtrawberry plant had not only been preſerved alive, expoſed in the middle of Nooth's machine, to copious ſtreams of fixed air, from the 23d of April to the 14th of May; but that the bloſſoms, which were only budded when put into the machine had actually expanded. A ſtrong proof that the plant had continued to vegetate. It was then alive, but

* Dr. Prieſtley was miſtaken in this ſuppoſition, as will appear in the ſequel.

† Theſe had been made previous to Dr. Prieſtley's requeſt.

rather drooping, and having been crufhed in taking out of the machine, was thrown away.

Two fprigs of mint, with fome loofe earth adhering to their roots, were alfo kept in fimilar veffels, from the 1ft of September to the 12th of the fame month. To the one a continued current of fixed air was fupplied. The roots of both were cut off on the 7th. The fprig in common air exhibited fymptoms of decay on the 12th day, but that in the ftream of fixed air continued frefh above a week, after that in the common air was decayed nearly to the top. The experiment was then difcontinued, and the remaining plant foon withered.

The next year I made the following experiments, which farther confirm the truth of the preceding ones which had been made both by you and myfelf. In thefe, as alfo in thofe juft related, the firft caufe of error was avoided, and the proportion of fixed air was, in fome of them, afcertained.

1777, April 11th, The weather being very cold and vegetation backward—The middle part of Nooth's machine was entirely filled with fixed air, by firft filling it with water, inverting it in the fame fluid, ftopping up the capillary tubes, and then driving out the water, from the veffel, by fixed air from an effervefcing mixture. The middle, was then immediately placed on the lower, part of the machine, containing an effervefcing mixture alfo, which had been working

for

for ſeveral minutes, and a crimſon polyanthos was introduced into the middle part, and ſuſpended by a ſtring. In paſſing through the mouth of the veſſel, the petals we neceſſarily compreſſed, and one or two received ſome damage. The effervescence was kept up briſkly.

On the ſame day, and into the ſame veſſel, a young ſprig of mint, with its root, was introduced, and a ſimilar ſprig was placed in a large glaſs decanter as a ſtandard. The edges of the former were much nipped by ſome ſevere winds which had prevailed, and had a yellowiſh hue.

The polyanthos did not begin to droop till the 15th. On the 16th it was taken out ſhrivelled, but the colour not changed.

The mint examined on the 12th was more freſh than when firſt put into the veſſel with fixed air. The next day two young ſhoots appeared more vigorous. On the 15th its appearance was more vivid than that in common air, but the next day it was apparently dead, and was taken out in a flaccid ſtate.*

April 26th, A polyanthos plant, with its root and flowers, was purchaſed in the market, with

* The machine having no valve, and having been violently ſhaken, I ſuſpected that ſome of the vitriolic acid had been forced up the tubes; for the moiſture, in the inſide of the veſſel, was more acid than it would have been from the fixed air only.

ſeveral

ſeveral others, and placed in Nooth's machine, where it was continued till the 10th of May. The effervefcence was frequently renewed for the firſt four days, then twice, and afterwards once a day, but the diſcharge of air was continually going on. It continued ten days without any ſigns of decay; and, when taken out of the machine on the 14th day, though ſome of the older flowers were fading, the others were as freſh and blooming as when firſt put into the veſſel. More ſo than thoſe of the other plants which had been purchaſed the ſame day, and had been planted in the garden. The body of the plant was green, ſucculent and undecayed. The air extinguiſhed flame, and, on trial, was $\frac{1}{3}$ fixed air; and during ſeveral days, the proportion of fixed air muſt have been larger.

But *confined* in veſſels of fixed air; or even in Nooth's machine, with the upper part and groved ſtopper put on, plants died ſooner than in common air. The air meaſured was $\frac{7}{8}$ fixed air.

I am informed that an ingenious philoſopher of Geneva has made ſome experiments, in which he has proved, not only, that phlogiſton is the food of plants, but alſo, to the ſatisfaction of Dr. Prieſtley, that it is in the form of fixed air, in proper proportion and place, that this pabulum is adminiſtered. The latter is the whole that we contended for; and, which, we thought, we had ſatis-

ſatisfactorily proved, eight years ſince. On this occaſion, therefore, I thought it not improper to recur to my journal of experiments, and to take this method of laying an account of them before the Literary and Philoſophical Society; in order to aſcertain your claim to the diſcovery in queſtion.

In regard to the animal body, it would ſurely be wrong to ſay that nothing was nutritious or ſalutary to it, but what it could bear to receive unmixed or undiluted. Why then may we not ſuppoſe that though fixed air, when pure, may be fatal to plants confined in it; and excluded from free communication with the common air, yet when applied in proper doſe, and to plants enjoying a free intercourſe with the atmoſphere, it may have a contrary effect, and ſerve to nouriſh and ſupport them?

But in Dr. Prieſtley's experiments, this *free intercourſe* does not appear to have been allowed; and herein, I apprehend, conſiſted the cauſe of the difference in our reſults.

At that time, the conſtitution of fixed air was not underſtood. It is now, *generally*, allowed to be formed by a combination of phlogiſton with the pure part of atmoſpheric air. The firſt of theſe ingredients has been proved, by the experiments of Dr. Prieſtley and others, to be favourable to vegetation, while plants droop and decay when expoſed to the action of the latter. It ſhould

ſhould further appear, from Dr. Ingenhouz's train of experiments, that plants have the power of ſeparating phlogiſton from common air, applying it to their nurture, and throwing out the pure or dephlogiſticated reſiduum, as excrementitious. Now allowing, what appears highly probable, that they have a ſimilar power of decompoſing *fixed air*, and of applying and rejecting its conſtituent parts, our method of conducting the experiments was *not* injurious to the proceſs; whereas, when confined in cloſe veſſels, as by Dr. Prieſtley, the plants would be ſuffocated, in a manner reverſed to what would happen to an animal. For as in that caſe, from a want of communication with the atmoſphere, as neceſſary to carry off the phlogiſton thrown out from the lungs, (according to the beautiful theory of reſpiration, advanced and ſo well ſupported by Dr. Prieſtley) the animal muſt periſh; ſo, in the other inſtance the plant would die, if cut off from the air of the atmoſphere, in ſuch manner, that the pure air excreted by its veſſels could not be conveyed from it. For, in theſe circumſtances, this fluid, ſo ſalutary to animal, but deſtructive to vegetable, life, muſt be accumulated in the body of the plant, and, its functions being thus impeded, death is the neceſſary conſequence.

This reaſoning ſeems to be confirmed by ſome of the facts which you have communicated to me, from your Journal. For it appears, from

ſeveral

ſeveral of your experiments, that during ſeven hours of the day, viz. from 10, A. M. to 5, P. M. the plants, you employed, were expoſed to varying proportions of fixed air, ſeldom exceeding $\frac{1}{2}$ the proportion of air, contained in the veſſel, and never leſs than $\frac{1}{4}$. But, from 5 o'clock in the evening till 10, the ſucceeding day, the quantity of fixed air ſeems to have varied, from $\frac{1}{2}$ to $\frac{1}{17}$ of the whole air. Now a plant expoſed to ſuch diverſified proportions of air, paſſing too in a ſtream through the veſſel, muſt be in a favourable ſtate, both for exhalation, and conſequently for the proceſs of inhalation alſo.

I am, dear SIR,

With the moſt perfect regard,

Your faithful, affectionate Friend,

THOMAS HENRY.

MANCHESTER, *May* 12, 1784.

OBSERVATIONS

Observations *on a* Thigh Bone *of* uncommon Length. *By* C. White, *Eſq.* F. R. S. *&c.* *Read November* 10, 1784.

IN different parts of Siberia, as well in the mountains as the valleys; likewiſe in Ruſſia, Germany, Peru, the Brazils, and North America, on the banks of the Ohio near the river Mimme, ſeven hundred miles from the ſea-coaſt, and five or ſix feet beneath the ſurface of the earth, there have frequently been found, at various times, foſſil tuſks and bones of a very large ſize, ſomewhat reſembling thoſe of the elephant. In temperate climates, the tuſks are ſoftened, and converted into foſſil ivory; but in countries frequently frozen they are generally found very freſh. Many of them may be ſeen in the Imperial Cabinet at Peterſburgh, in the Britiſh, Dr. Hunter's, and Sir Aſhton Lever's Muſeums, and in that of the Royal Society. According to tradition, theſe were reported to be the tuſks and bones of the *Mammouth*, an animal, which, if ever it exiſted, is not now, that we know, any longer an inhabitant of any part of this globe. A deſcription of the Mammouth is

is given by Muller.* This animal, he ſays, is four or five yards high, and about thirty feet long. His colour is greyiſh. His head is very long, and his front very broad. On each ſide, preciſely under the eyes, there are two horns, which he can move and croſs at pleaſure. In walking he has the power of extending and contracting his body to a great degree. Iſbrandes Ides gives a ſimilar account; but he is candid enough to acknowledge, that he never knew any perſon who had ſeen the Mammouth alive. Mr. Pennant, however, thinks it "more than "probable, that it ſtill exiſts in ſome of thoſe "remote parts of the vaſt new Continent, impe"netrated yet by Europeans. Providence," he adds, "maintains and continues every created "ſpecies; and we have as much aſſurance, that "no race of animals will any more ceaſe while "the earth remaineth, than *ſeed time and harveſt,* "*cold and heat, ſummer and winter, day and night.*"

Several eminent naturaliſts of late years, as Sir Hans Sloane, † Gmelin, ‡ Daubenton, and Buffon, are of opinion that theſe prodigious bones and tuſks are really the bones and tuſks

* Moeurs & Uſages des Oſtiaques dans *le Recucil des Voyages au Nord.*

† Hiſtoire de l'Acad. des Sciences Ann. 1717. p. 1.

‡ Relation d'un Voyage a Kamtſchatka par M. Gmelin en 1735.—*A Peterſburgh-en langue Ruſſe.*

of

of elephants; and many modern philosophers have held the Mammouth to be as fabulous as the Centaur.

The great difference in size they endeavour to account for, as arising from difference in age, sex, and climate; and the cause of their being found in those northern parts of the world, where elephants are no longer natives, nor can even long exist, they presume to have arisen from hence; that, in the great revolutions which have happened in the earth, the elephants, to avoid destruction, have left their native country, and dispersed themselves wherever they could find safety. Their lot has been different. Some in a longer, and others in a shorter time after their death, have been transported to great distances by some vast inundations. Those, on the contrary, which survived, and wandered far to the north, must necessarily have fallen victims to the rigours of the climate. Others, without reaching to so great a distance, might be drowned, or perish with fatigue.

In the year 1767, Dr. Hunter, with the assistance of his brother, Mr. J. Hunter, had an opportunity of investigating more particularly this part of natural history, and has evidently proved, that these fossil bones and tusks are not only larger than the generality of elephants, but that the tusks are more twisted, or have more of the spiral curve than elephants' teeth, and that the

the thigh and jaw bones differ in ſeveral reſpects from thoſe of the elephant; but what put the matter beyond all diſpute, was the ſhape of the grinders, which clearly appeared to be thoſe of a carnivorous animal, or at leaſt of an animal of the mixed kind, being furniſhed with a double row of high and conic proceſſes, as if intended to maſticate, not to grind the food, and the enamel making a cruſt on the *outſide* only of the teeth, as in a human grinder. They totally differ from thoſe of the elephant, which is well known not to be of the carnivorous, but graminiverous kind, both by the form of its grinders, and by its never taſting animal food. A few years ago, I had in my poſſeſſion an elephant's grinder, which Sir Aſhton Lever did me the honour to place in his elegant Muſeum. This is flat, and ribbed tranſverſely on its ſurface.

Some have ſuppoſed theſe foſſil bones to belong to the hippopotamus, or river horſe; but there are many reaſons againſt this ſuppoſition, as the hippopotamus is even much ſmaller than the elephant, and has ſuch remarkably ſhort legs, that his belly reaches within three or four inches of the ground.

The late Dr. Hunter, in a paper on this ſubject, read before the Royal Society the 15th of February 1768, and publiſhed in the tranſactions of that year, gives a particular account of ſeveral tuſks and grinders in the tower, which came from the Ohio, and others which Dr.

Franklin had received from the ſame place. Theſe tuſks and grinders, Dr. Hunter was fully convinced, were not, as was ſuppoſed, of the American elephant, but belonged to an animal of another ſpecies, a *pſeud-elephant*, or *animal incognitum* as he calls it, which naturaliſts are now unacquainted with; and from the form of the knobs on the body of the grinders, and the diſpoſition of the enamel on them, which makes a cruſt on the outſide only of the tooth, as in a human grinder, his brother Mr. J. Hunter was convinced that the animal was either carnivorous, or of a mixed kind. Thoſe who wiſh to have a further account of this ſubject, I muſt beg leave to refer to the doctor's ingenious paper.

The thigh bone, which I have now the honour to ſhew to this Society, was given to me by Mr. Hardman, of Ardwick, who purchaſed it at Liverpool. It was found in a room in that town, from whence ſome people, who kept wild beaſts, had ſuddenly decamped in the night, and, it is ſuppoſed, left this bone behind them. This is all I could learn of its hiſtory. It is evidently the left thigh bone of ſome amazingly large animal. The *length* of it, is three feet ten inches and ſix lines; the *breadth*, in the narroweſt part, four inches and ſeven lines. Its *thickneſs*, two inches and nine lines. Its ſmalleſt *circumference*, one foot and one inch; and its *weight*, forty pounds eight ounces.

On comparing this bone with the femurs

of

of Canada and Siberia, and with that of the common elephant, feven feet and a half high, defcribed by Mr. Daubenton, in the Memoirs of the Royal Academy of Sciences of Paris, for the year 1762, it appears to bear the greateft refemblance to that of Siberia. It is longer than any of them by feveral inches, and is, perhaps, the longeft thigh bone of any animal, of which an account has been given by any author we are acquainted with. It is neither fo heavy, nor fo thick, as the one from Canada, but its weight is greater than that from Siberia, and much exceeds that of the common elephant.* Dr. Hunter, in the paper before referred to, feems to have brought pretty pofitive proof, that thefe two femurs (that from Canada, and that from Siberia) are not the femurs of the elephant; and as this thigh bone before us has fo great a fimilitude to thefe two, particularly to that from Siberia, there is every reafon to be of the fame opinion with regard to it. Whether the animal defcribed by Muller, under the name Mammouth, has ever exifted, or whether, as Mr. Pennant feems to fuppofe, it ftill exifts in any parts of the world, yet unexplored, may long remain undetermined.

* Since this paper was read before the Society, the Rev. James Douglas has fent me an account of a thigh bone of this animal, in the Borough, much larger than any of thefe. It weighs upwards of eighty pounds, and is nearly four feet in length.

 But

But from the ſhape and ſize of the femurs, and of the temporal, and jaw bone, there is little room to doubt their having belonged to an animal, with which we are now entirely unacquainted, and of which there are no further traces remaining. It appears to have been larger than the generality, at leaſt, of elephants, or than any other quadruped we know; and, from the ſhape and nature of the grinders, it muſt evidently have been a carnivorous animal.

I have here ſubjoined a comparative view of the femurs of Canada, Siberia, and that of the common elephant, with my own; the account of the former is extracted from Mr. Daubenton's before-mentioned. The circumference, breadth, and thickneſs, are taken at the ſmalleſt part of the bones The length is meaſured from the upper part of the head, to the loweſt extremity of the inner condyle.

Femur of *Canada*.				Of *Siberia*.			Of *Verſailles*.			Mr. *White's*		
	Feet.	Inch.	Lines.	Ft.	In.	Lines.	Ft.	In.	Lines.	Ft.	In	Lines.
Length	3	4	9	3	4	0 without Epiph.	2	10	3	3	10	6
				3	5	0 with Epiph.						
Breadth	0	6	8	0	5	8	0	3	2	0	4	7
Thickneſs	0	3	9	0	3½	0	0	2	4½	0	2	9
Circum.	1	4	9	1	3	1	0	9	1	1	1	0
Weight	59 pound.			38 pound 6½ oz.			10 pound 12 oz.			40 pound 8 oz.		

I have alſo made a drawing of the bone in my poſſeſſion, and reduced it to the ſame ſcale with the

the other three; more fully to ſhew the proportionable ſize of them; and of the jaw bone and grinders of the elephant, and animal *incognitum*, or *pſeud-elephant* taken from Dr. Hunter's plate of them.

METEOROLOGICAL IMAGINATIONS *and* CONJECTURES. *By* BENJAMIN FRANKLIN, LL.D. F. R. S. *and Acad. Reg. Scient. Paris. Soc. &c. Communicated by Dr.* PERCIVAL. *Read December* 22, 1784.

THERE ſeems to be a region higher in the air over all countries, where it is always winter, where froſt exiſts continually, ſince, in the midſt of ſummer on the ſurface of the earth, ice falls often from above in the form of hail.

Hailſtones, of the great weight we ſometimes find them, did not probably acquire their magnitude before they began to deſcend. The air, being eight hundred times rarer than water, is unable to ſupport it but in the ſhape of vapour, a ſtate in which its particles are ſeparated. As ſoon as they are condenſed by the cold of the upper region, ſo as to form a drop, that drop begins to fall. If it freezes into a grain of

ice, that ice defcends. In defcending, both the drop of water, and the grain of ice, are augmented by particles of the vapour they pafs through in falling, and which they condenfe by their coldnefs, and attach to themfelves.

It is poffible that, in fummer, much of what is rain, when it arrives at the furface of the earth, might have been fnow, when it began its defcent; but being thawed, in paffing through the warm air near the furface, it is changed from fnow into rain.

How immenfely cold muft be the original particle of hail, which forms the center of the future hailftone, fince it is capable of communicating fufficient cold, if I may fo fpeak, to freeze all the mafs of vapour condenfed round it, and form a lump of perhaps fix or eight ounces in weight!

When, in fummer time, the fun is high, and continues long every day above the horizon, his rays ftrike the earth more directly, and with longer continuance, than in the winter; hence, the furface is more heated, and to a greater depth, by the effect of thofe rays.

When rain falls on the heated earth, and foaks down into it, it carries down with it a great part of the heat, which by that means defcends ftill deeper.

The mafs of earth, to the depth perhaps of thirty feet, being thus heated to a certain degree, continues

continues to retain its heat for ſome time. Thus the firſt ſnows that fall in the beginning of winter, ſeldom lie long on the ſurface, but are ſoon melted, and ſoon abſorbed. After which, the winds that blow over the country on which the ſnows had fallen, are not rendered ſo cold as they would have been by thoſe ſnows, if they had remained. And thus the approach of the ſeverity of winter is retarded; and the extreme degree of its cold is not always at the time we might expect it, viz. when the ſun is at its greateſt diſtance, and the day ſhorteſt, but ſome time after that period, according to the Engliſh proverb, which ſays, "as the day lengthens, the "cold ſtrengthens;" the cauſes of refrigeration continuing to operate, while the ſun returns too ſlowly, and his force continues too weak to counteract them.

During ſeveral of the ſummer months of the year 1783, when the effect of the ſun's rays to heat the earth in theſe northern regions ſhould have been greateſt, there exiſted a conſtant fog over all Europe, and great part of North America. This fog was of a permanent nature; it was dry, and the rays of the ſun ſeemed to have little effect towards diſſipating it, as they eaſily do a moiſt fog, ariſing from water. They were indeed rendered ſo faint in paſſing through it, that when collected in the focus of a burning glaſs, they would ſcarce kindle brown paper.

 Of

Of courſe, their ſummer effect in heating the earth was exceedingly diminiſhed.

Hence the ſurface was early frozen.

Hence the firſt ſnows remained on it unmelted, and received continual additions.

Hence the air was more chilled, and the winds more ſeverely cold.

Hence perhaps the winter of 1783-4, was more ſevere, than any that had happened for many years.

The cauſe of this univerſal fog is not yet aſcertained. Whether it was adventitious to this earth, and merely a ſmoke, proceeding from the conſumption by fire of ſome of thoſe great burning balls or globes which we happen to meet with in our rapid courſe round the ſun, and which are ſometimes ſeen to kindle and be deſtroyed in paſſing our atmoſphere, and whoſe ſmoke might be attracted and retained by our earth; or whether it was the vaſt quantity of ſmoke, long continuing to iſſue during the ſummer from *Hecla* in Iceland, and that other volcano which aroſe out of the ſea near that iſland, which ſmoke might be ſpread by various winds, over the northern part of the world, is yet uncertain.

It ſeems however worth the enquiry, whether other hard winters, recorded in hiſtory, were preceded by ſimilar permanent and widely extended ſummer fogs. Becauſe, if found to be

ſo, men might from ſuch fogs conjecture the probability of a ſucceeding hard winter, and of the damage to be expected by the breaking up of frozen rivers in the ſpring; and take ſuch meaſures as are poſſible and practicable, to ſecure themſelves and effects from the miſchiefs that attended the laſt.

PASSY, *May* 1784.

A ſhort ACCOUNT *of an* EXCURSION *through the* SUBTERRANEOUS CAVERN *at* PARIS. *By Mr.* THOMAS WHITE, *Member of the Royal Medical Society of Edinburgh, &c. &c. in a* LETTER *to his* FATHER. *Read February* 9, 1785.

PARIS, *July* 29, 1784.

I YESTERDAY viſited a moſt extraordinary ſubterraneous Cavern, commonly called the Quarries. But before I give you the hiſtory of my expedition it will perhaps be neceſſary to ſay a few words concerning the *obſervatoire royal*, the place of deſcent into this very remarkable cavern. This edifice is ſituated in the Faux-bourg St. Jacques, in the higheſt part of the city. It takes its name from its uſe, and was built by Louis XIV. in 1667, after the deſign of Claude

Claude Perrault, Member of the Academy of Sciences, and firſt architect to his majeſty. It ſerves for the reſidence of mathematicians, appointed by the king, to make obſervations, and improve aſtronomy. The mode of building it is ingenious, and admirably contrived, it being ſo well arched that neither wood nor iron are employed in its conſtruction. All the ſtones have been well choſen, and placed with an uniformity and equality which contribute much to the beauty and ſolidity of the whole edifice. It is reckoned to be about eighty or ninety feet in height, and at the top there is a beautiful platform, paved with flint ſtones, which commands an excellent view of Paris, and its environs. In the different floors of this building, there are a number of trap-doors, placed perpendicularly over each other, and, when theſe are opened, the ſtars may be very clearly diſtinguiſhed, from the bottom of the cave, at noon day.

At this place, I was introduced to one of the inſpectors, (perſons appointed by the king to ſuperintend the workmen) by my friend Mr. Smeathman, who had uſed great application and intereſt for permiſſion to inſpect the quarry, and had been fortunate enough to obtain it. For as this cavern is extended under a great part of the city of Paris, and leaves it in ſome places almoſt entirely without ſupport, the inſpectors are very particular as to ſhewing it, and endeavour

deavour to keep it as ſecret as poſſible, leſt, if it ſhould get generally known, it might prove a ſource of uneaſineſs and alarm to the inhabitants above. For, what is very remarkable, notwithſtanding the extent of this quarry, and the apparent danger many parts of the city are in from it, few, even of thoſe who have conſtantly reſided at Paris, are at all acquainted with it, and on my mentioning the expedition I was going to undertake to ſeveral of my Pariſian friends, they ridiculed me upon it, and told me it was impoſſible there could be any ſuch place.

About nine o'clock in the morning we aſſembled to the number of forty, and, with each a wax candle in his hand, preciſely at ten o'clock, deſcended, by ſteps, to the depth of three hundred and ſixty feet perpendicular. We had likewiſe a number of guides with torches, which we found very uſeful; but, even with theſe aſſiſtants, we were ſeveral times under the neceſſity of halting, to examine the plans the inſpectors keep of theſe quarries, that we might direct our courſe in the right road. I was diſappointed in not being able to obtain one of theſe plans, which would have given the cleareſt idea of this moſt extraordinary place. At the entrance, the path is narrow for a conſiderable way; but ſoon we entered large and ſpacious ſtreets, all marked with names, the ſame as in the city; different advertiſements and bills were

found,

found, as we proceeded, pafted on the walls, fo that it had every appearance of a large town, fwallowed up in the earth.

The general height of the roof is about nine or ten feet; but in fome parts not lefs than thirty, and even forty. In many places, there is a liquor continually dropping from it, which congeals immediately, and forms a fpecies of tranfparent ftone, but not fo fine and clear as rock cryftal. As we continued our peregrination, we thought ourfelves in no fmall danger from the roof, which we found but indifferently propped in fome places with wood much decayed. Under the houfes, and many of the ftreets, however, it feemed to be tolerably fecured by immenfe ftones fet in mortar; in other parts, where there are only fields or gardens above, it was totally unfupported for a confiderable fpace, the roof being perfectly level, or a plane piece of rock.

After traverfing about two miles, we again defcended about twenty fteps, and here found fome workmen, in a very cold and damp place, propping up a moft dangerous part, which they were fearful would give way, every moment. We were glad to give them money for fome drink, and make our vifit at this place as fhort as poffible. The path here is not more than three feet in width, and the roof fo low, that we were obliged to ftoop confiderably.

By

By this time, ſeveral of the party began to repent of their journey, and were much afraid of the damp and cold air we frequently experienced. But, alas! there was no retreating.

On walking ſome little diſtance farther, we entered into a kind of ſalon, cut out of the rock, and ſaid to be exactly under the *Egliſe de St. Jaques.* This was illuminated with great taſte, occaſioned an agreeable ſurprize, and made us all ample amends for the danger and difficulty we had juſt before gone through. At one end, was a repreſentation in miniature of ſome of the principal forts in the Indies, with the fortifications, draw-bridges, &c. Cannons were planted, with a couple of ſoldiers to each, ready to fire. Centinels were placed in different parts of the garriſon, particularly before the governor's houſe; and a regiment of armed men was drawn up in another place, with their general in the front. The whole was made up of a kind of clay which the place affords, was ingeniouſly contrived, and the light that was thrown upon it, gave it a very pretty effect.

On the other ſide of this hall, was a long table ſet out with cold tongues, bread and butter, and ſome of the beſt Burgundy I ever drank. Now every thing was hilarity and mirth; our fears were entirely diſpelled, and the danger we dreaded, the moment before, was now no longer thought of. In ſhort, we were all in good ſpirits again,

again, and proceeded on our journey about two miles further, when our guides judged it prudent for us to afcend, as we were then got to the fteps which lead up to the town. We here found ourfelves fafe, at the *Val de grace,* near to the Englifh benedictine convent, without the leaft accident having happened to any one of the party. We imagined we had walked about two French leagues, and were abfent from the furface of the earth, betwixt four and five hours.

After we had thanked the infpectors and guides for their very great civility, politenefs, and attention, we took our leave to vifit the Englifh benedictines convent, in whofe court yard, and within a few yards of their houfe, the roof of the fubterraneous paffage had given way, and fallen in, the depth of one hundred and ninety three feet.

Though there were fome little danger attending our rafh expedition (as fome people were pleafed to term it) yet it was mòft exceedingly agreeable, and fo perfectly a *nouvelle* fcene, that we were all highly delighted, and thought ourfelves amply repaid for our trouble.

I regretted much that I did not take a thermometer and barometer down with me, that I might have had an opportunity of making fome remarks, on the temperature and weight of the air. Certainly, however, it was colder at this time than on the furface of the earth.

But

But Mr. Smeathman informed me, that when he defcended the laft winter, in the long and hard froft, he found the air much more temperate than above ground, but far from warm. Neither, however, had he a thermometer with him. I lamented too that I had not time to make more remarks on the petrefactions, &c.

Mr. Smeathman obferved, that when he defcended, he found a very fenfible difficulty of breathing in fome of the paffages and caverns, where the fuperincumbent rock was low, and the company crowded. This no doubt was much increafed by the number of perfons and of wax lights, but he does not apprehend that the difficulty would have been fo great in rooms of equal dimenfions above ground. We remarked too, when we defcended, that there was, in fome degree, an oppreffion of refpiration throughout the whole paffage.

There were formerly feveral openings into the quarries, but the two I have mentioned, viz. the *Obfervatory* and the *Val de Grace*, are, I believe, the only ones left; and thefe the infpectors keep conftantly locked, and rarely open them, except to ftrangers particularly introduced, and to workmen who are always employed in fome part by the King.

The Police thought it a neceffary precaution to fecure all the entrances into this cavern, from its having been formerly inhabited by a famous gang

gang of robbers, who infested the country for many years round the city of Paris.

As to the origin of this quarry, I could not, on the strictest inquiry, learn any thing satisfactory; and the only account I know published, is contained in the *Tableaux de Paris Nouvelle edition, tom premier, chapitre 5me. page 12me.*

"Pour batir Paris dans son origine, il a fallu "prendre la Pierre dans les Environs; la con-"sommation n'en a pas êté mince. Paris "s'agrandissant on a bâti insensiblement les "Fauxbourgs sur les anciennes Carriers, de "sorte que tout ce qu'on voit en dehors, man-"que essentiellement dans la terre aux Fonde-"ment de la Ville; de la, les Concavites effray-"antes, qui se trouvent adjound'hui sous les "maisons de plusieurs quartiers; elles portent "sur les Abymes. Il ne foudroit pas un choc "bien considerable, pour ramener les pierres au "point d'ou on les a enleves avec tout d'effort. "Huit personnes ensevelies dans un Gouffre de "cent cinquante Pieds de Profondeur, et quel-"ques autres accidens moins connus, ont excité "enfin la vigilance de la Police, et du gou-"vernement; & de fait, on a etagé en silence "les edifices de plusieurs quartiers, en leur "donnant dans ces obscurs Souterreins un apui "qu'ils n'avoient pas.

"Tout le Fauxbourgs Saint Jacques, la Rue "de la Harpe, & meme la Rue de Tournon,

"portent

" portent fur d'anciennes Carriers, & ,,i1 · a
" bati des Pilaftres pour foutenir le P(... s
" Maifons. Que de matiere a reflexion. ...
" confiderant cette grande ville formée, & ...
" tenue par moyens abfolument contraires! les
" Clochers, ces Vontes des temples, autant
" de fignes, qui difent a l'oeil ce que nous
" voyons en l'air manque fous nous Pieds."

" For the firft building of Paris, it was necef-
" fary to get the ftone in the environs, and the
" confumption of it was very confiderable. As
" Paris was enlarged, the fuburbs were infenfibly
" built on the ancient quarries, fo that, all that
" you fee without is effentially wanting in the
" earth, for the foundation of the city: hence
" proceed the frightful cavities, which are at
" this time found under the houfes in feveral
" quarters. They ftand upon abyffes. It would
" not require a very violent fhock to throw back
" the ftones to the place, from whence they
" have been raifed with fo much difficulty.
" Eight men being fwallowed up in a gulph one
" hundred and fifty feet deep, and fome other
" lefs known accidents, excited at length the
" vigilance of the Police and the government,
" and, in fact, the buildings of feveral quarters
" have been privately propped up; and by this
" means, a fupport given to thefe obfcure fub-
" terraneous places, which they before wanted.

"All the ſuburbs of St. James's, Harp-ſtreet, "and even the ſtreet of Tournon, ſtand upon "the ancient quarries; and pillars have been "erected to ſupport the weight of the houſes. "What a ſubject for reflections, in conſidering "this great city formed, and ſupported by "means abſolutely contrary! Theſe towers, "theſe ſteeples, the arched roofs of theſe temples "are ſo many ſigns to tell the eye, that what "we now ſee in the air, is wanting under our "feet."

A DESCRIPTION *of a* NEW INSTRUMENT *for meaſuring the* SPECIFIC GRAVITY *of* BODIES. *By Mr.* WILLIAM NICHOLSON, *in a* LETTER *to Mr.* J. H. MAGELLAN, F. R. S. *Reg. Acad. Petropol. & Paris. Correſp. &c. Read May* 4, 1785.

DEAR SIR,

ACCORDING to my promiſe, I tranſmit to you an account of the Inſtrument I have conſtructed for the eaſy and exact finding the ſpecific gravities of bodies. It appears to me to be as perfect, as the nature of a floating inſtrument of this kind will admit of; and, for that reaſon, I preſume it will not be impertinent to mention

mention previously what has been done in this way.

It seems to follow from a passage in Boyle's account of a new Essay Instrument, * that the Hydrometer, or Areometer was first invented by that great philosopher. The essay instrument here mentioned, was intended for the hydrostatical proof of metals, and was adapted to serve chiefly for guineas. It consisted of a ball, somewhat less than an hen's egg, with a stem of four or five inches in length, soldered to the upper part, and a bent wire or stirrup beneath, to place the coin upon. A slit piece of brass, with a lateral screw to hold the coin tight, though in fact conducing more to the ease than accuracy of the experiment, is mentioned by the author, as being preferable to the stirrup: and, to extend the use of the instrument, he proposes that the ball be made large, and provided with a contrivance for occasionally changing the quantity of ballast applied beneath the ball.

Boyle's instrument was intended to be used in water, and, consequently, the graduations of its stem denoted certain invariable weights. But when the hydrometer is to be used in various fluids, it diminishes the accuracy of the results,

* Lowthorp's Abridgement of the Philosophical Transactions, vol. I. p. 604. Or Boyle's Works in 4to. edit. London, 1772, vol. IV. p. 204.

if thofe fpaces be taken for abfolute weights; or, at all events, it brings forward a rather intricate confideration of the relation which the bulks of the fpaces, or parts of the ftem, have to the whole immerfed part. This appears to have been the inducement that led M. G. Fahrenheit * to add a fmall difh or fcale to the top of the upper ftem, which, inftead of graduations, had only a fingle mark that, in all cafes, was to be brought to the furface of the fluid, by means of weights added in the faid fcale.

Mr. Clarke, † who in the year 1730 publifhed an account of an hydrometer, does not appear to have been apprifed of what had been done before by Boyle and Fahrenheit. For he fpeaks of his own inftrument as a new invention, though it does not differ from that of Boyle, except in having a great number of ballaft weights to be fcrewed occafionally to the lower ftem, inftead of depending on the graduations of the upper ftem; and he affirms, that the fpecific gravities of fluids cannot be found without a great deal of trouble, though it is certain that they may be found with greater eafe, and much more accuracy, by that of Fahrenheit, than by his own. Clarke's hydrometer, with weights adapted to

* Reid and Gray's Abridgment of the Phil. Tranf. vol. VI. part I. p. 294.

† Ibid. vol. VI. part I. p. 295.

allow

allow for the diminution of ſpecific gravity, which ariſes from the thermometrical expanſion of fluids, is uſed by the officers of exciſe.

This hydrometer is inferior to Fahrenheit's in two reſpects. In the firſt place, either a bubble of air, or a portion of the fluid, will lie hid in that part of the cavity of the ballaſt weight, which is not filled by the ſcrew; and it is of very different conſequence, which of the two is there. And ſecondly, the weights acting on the inſtrument, by their reſidual gravity, will not be conſtant; or, in other words, an additional weight will be accompanied by an addition to the bulk of the immerſed part of the inſtrument: and, in the caſe where the ſpecific gravity of the liquid is not given, but required, it will not be eaſy to determine how much the operation of the one is counteracted by that of the other. However, though this laſt conſideration evinces that the inſtrument is not fit for general uſe, yet it is accurate for the trial of ardent ſpirit, or any other particular liquid, when the weights are adjuſted by experiment to the intended uſe.

Poſterior to theſe, there have been ſeveral attempts to improve the hydrometer, but as they have been aimed chiefly to render it more perfect or convenient, with reſpect to the ſingle uſe of proving ſpirits, it is unneceſſary to deſcribe them at large. Among theſe it is however proper to mention thoſe of Dr. G. Fordyce, and

Mr. Quin. The firſt is certainly the moſt perfect inſtrument we poſſeſs, its weights being adjuſted to the different ſpecific gravities of ſpirits, by experiments made at numerous varieties of ſtrength and temperature. The latter having no additional weights, but depending entirely on the graduations of its ſtem, is much more ready in practice. All its originality conſiſts in its ſtem being the fruſtum of a cone, whoſe larger end is uppermoſt, by which happy contrivance the ſtem is ſhortened, and its graduations are all kept nearly equal.

I ſhall now proceed to deſcribe the inſtrument I have cauſed to be made for the general purpoſes of finding the ſpecific gravities of bodies. Its dimenſions are likewiſe added. *

AA repreſents a ſmall ſcale. It may be taken off at D. Diameter $1\frac{1}{2}$ inch. Weight 44 grains.

B a ſtem of hardened ſteel wire. Diameter $\frac{1}{100}$ inch.

E a hollow copper globe. Diameter $2\frac{8}{10}$ inches. Weight with ſtem 369 grains.

FF a ſtirrup of wire ſcrewed to the globe at C.

G a ſmall ſcale ſerving likewiſe as a counterpoiſe. Diameter $1\frac{1}{2}$ inch. Weight with ſtirrup 1634 grains.

* See the figure to which theſe letters refer in plate II. vol. II.

The


Fig. 1
Fig. 2
Fig 3
Fig. 4
Fig. 5
Fig. 6
A
A
D
B
E

The other dimensions may be had from the drawing, which is $\frac{1}{3}$ of the linear magnitude of the instrument itself.

In the construction, it is assumed that the upper scale shall constantly carry 1000 grains when the lower scale is empty, and the instrument sunk in distilled water at the temperature of 60° Fahrenheit, to the middle of the wire or stem. The length of the stem is arbitrary, as is likewise the distance of the lower scale from the surface of the globe. But the length of the stem being settled, the lower scale may be made lighter, and, consequently, the globe less, the greater its distance is taken from the surface of the globe; and the contrary. It is to be noted that the diameter of each scale must not be less than the side of a cube of water weighing 1000 grains.

The distances of the upper and lower scales, respectively, from the nearest surface of the globe being settled, add half the side of a cube of water weighing 1000 grains to the distance of the upper scale. This increased distance, and the said distance of the lower scale, may be considered as the two arms of a lever; and, by the property of that mechanical power,

As the number expressing the lower distance

Is to the whole weight above; namely 1000 grains added to the weight of the upper scale,

 So

So is the number expreſſing the upper diſtance,

To the lower weight, when the inſtrument has no tendency to any one poſition.

This laſt found weight muſt be conſiderably increaſed, in order that the inſtruments may acquire and preſerve a perpendicular poſition.

Add together, into one ſum, the weight of the lower ſcale thus found, the weight of the upper ſcale and its load, and the eſtimate weight of the ball and wires. Find the ſolid content of an equal weight of water; and thence, by the common rules of menſuration the diameter of an equal ſphere. This will be the diameter, from outſide to outſide, of the globe that will float the whole.

As this proceſs, and every other part of the preſent letter, may be eaſily deduced from the well known laws of hydroſtatics; I forbear enlarging on the demonſtrative part, and ſhall proceed to indicate the uſe of the inſtrument in the ſame curſory manner.

To meaſure the ſpecific gravities, and thermometrical expanſions, of FLUIDS. If the extreme length or height of the inſtrument be moderate, its weight, when loaded, will be about 3100 grains. It is, however, neceſſary in practice, that its weight ſhould be accurately found by experiment. This whole weight is equal to that of a quantity of diſtilled water, at the temperature of 60°, whoſe bulk is equal to that part of the

the instrument which is below the middle of the stem. If, therefore, the instrument be immersed to the middle of the stem, in any other fluid at the same temperature (which may be done by altering the load) the difference between this last load and 1000 grains, will be the difference between equal bulks of water, and of the other fluid, the weight of the mass of water being known to be 3100 grains. If the said difference be *excess* above 1000 grains it must be added, or if it be *defect* subtracted from 3100 grains: the sum or remainder will be a number, whose ratio to 3100 will express the ratio of the specific gravity of the assumed fluid to that of water. And this ratio will be expressed with considerable accuracy; for the instrument having a cylindrical stem of no more than $\frac{1}{40}$ of an inch diameter, will be raised or depressed near one inch by the subtraction or addition of $\frac{1}{10}$ of a grain, and will therefore indicate with ease such mutations of weight as do not fall short of $\frac{1}{20}$ of a grain, or $\frac{1}{62000}$th part of the whole. Consequently, the specific gravities of all fluids, in which this instrument can be immersed, will be found to five places of figures.

It is evident, that this instrument is a kind of *thermometer*, perhaps better adapted than the common one, for measuring the expansions of fluids by heat. As the fluid, in the common thermometer, *rises* by the excess of expansion of

of the fluid beyond the expansion of the glass vessel, so our instrument will *fall* by the excess of the same expansion, beyond the proper expansion of the materials it is composed of.

To *measure the specific gravities* of SOLID BODIES. The solid bodies, to be tried by this instrument must not exceed 1000 grains in weight. Place the instrument in distilled water, and load the upper scale or dish, till the surface of the water intersects the middle of the stem. If the weights required to affect this be exactly 1000 grains, the temperature of the water answers to 60° of Fahrenheit's scale; if they be more or less than 1000 grains, it follows, that the water is colder or warmer. Having taken a note of this weight, unload the scale, and place therein the body, whose specific gravity is required. Add more weight, till the surface of the water again bisects the stem. The difference between the added weight, and the former load, is the weight of the body in air. Place now the body in the lower scale or dish under water, and add weights in the upper scale, till the surface of the water once more bisects the stem. This last added weight will be the difference between 1000 grains, and the weight of the body in water. To illustrate this by an example.

N. B. The specific gravity of lead and tin, (and probably other metals) will vary in the third

third figure, when the ſame piece of metal is melted and cooled a ſecond time. This difference probably ariſes from the arrangement of the parts in cooling more or leſs ſuddenly.

The load was found by experiment	999	:	10 grains.
A piece of caſt lead required the additional weight	210	:	85
Difference is abſolute weight in air	788	:	25
Additional weight when the lead was in the lower ſcale	280	:	09
Difference between the two additional weights or loſs by immerſion	69	:	24

Hence ſpecific gravity $\dfrac{788.25}{69.24}$ $\dfrac{11384.}{1000}$

When the inſtrument is once adjuſted in diſtilled water, common water may be afterwards uſed. For the ratio of the ſpecific gravity of the water made uſe of to that of diſtilled water being known $(=\frac{b}{a})$, and the ratio of the ſpecific gravity of the ſolid to the water made uſe of being alſo known $(=\frac{c}{b})$, the ratio of the ſpecific gravity of the ſolid to that of diſtilled water will be compounded of both (that is, $\frac{cb}{ab}$.)

There is reaſon to conclude from the experiments of various authors, that they have not paid much attention either to the temperature or ſpecific gravity of the water they made uſe of.

of. They who are inclined to be contented with a less degree of precision than is intended in the construction here described, may change the stem, which for that purpose may be made to take out, for a larger.

One of the greatest difficulties that attends hydrostatical experiments, arises from the attraction or repulsion that obtains at the surface of the water. After trying many expedients to obviate the irregularities arising from this cause, I find reason to prefer the simple one, of carefully wiping the whole instrument, and especially the stem, with a clean cloth. The weights in the dish must not be esteemed accurate, while there is either a cumulus, or a cavity, in the water round the stem.

I am, Dear Sir,

Your affectionate humble Servant,

WILLIAM NICHOLSON.

London, *June* 1, 1784.

MEMOIRS *of the late Dr.* BELL, *by* JAMES CURRIE, M. D. *addreſſed to the* PRESIDENTS *and* MEMBERS *of the* LITERARY *and* PHILOSOPHICAL SOCIETY *of* MANCHESTER.* *Read March* 23, 1785.

GENTLEMEN,

THE reſpect which you have expreſſed for our late member, Dr. GEORGE BELL, by the Reſolutions of the Society, which occaſion this addreſs, cannot fail to be highly pleaſing to all thoſe who honour his memory. To me this at-

* At a meeting of the Literary and Philoſophical Society of Mancheſter, held February 4, 1784.

1. Reſolved, as a mark of reſpect to the memory of George Bell, M. D. That a tranſlation be made of his Inaugural Diſſertation de Phyſiologia Plantarum—That ſome brief Memoirs of the Author be prefixed to it, and that the whole be inſerted in the Journals of this Society.

2. That *James Currie*, M. D. the friend of Dr. Bell, and an Honorary Member of this Society, be requeſted to make the tranſlation, and furniſh the Memoirs ſpecified in the above reſolution.

3. Reſolved, that a copy of theſe reſolutions be tranſmitted to Dr. Currie, by the acting ſecretary of the Society.

tention

tention is particularly grateful; and I ſhould not have been ſo ſlow in executing the taſk which you aſſigned me, had not long continued ſickneſs deprived me of the power. Now that my ſtrength is in ſome meaſure reſtored, I embrace the earlieſt opportunity of preſenting the tranſlation which you have requeſted; and more fully to comply with your wiſhes, I ſhall prefix a ſhort hiſtory of the life of my much lamented friend.

Dr. Bell was born at his father's eſtate, in the county of Dumfries, in the autumn of the year 1755. He was the younger ſon of *Richard Bell* of *Greenhill*, by Miſs *Carruthers* of *Dormont*; and, by both ſides of the houſe, was deſcended of families which claim high antiquity in that country, though little known to fame. The rudiments of his education he received at home, and he was very early diſtinguiſhed by the quickneſs of his apprehenſion, and the general brilliancy of his parts. While he was yet very young, he had the misfortune to loſe his father, who died at *Bath* in the year 1766. This loſs was, however, in a great meaſure ſupplied by the care of his mother, who yet ſurvives to be a bleſſing to her friends; and by the counſel and example of his brother, who, though very young, already diſplayed an uncommon degree of prudence and virtue. By them, Dr. *Bell* was placed at the public ſchool of *Annan*, then conducted by the Rev. Mr. *Wright*, in whoſe houſe he

he reſided. Here he continued ſeveral years, and made a rapid progreſs in claſſical literature. In the year 1769, Mr. *Wright* being appointed miniſter of the pariſh of *New Abbey*, in the neighbourhood of *Dumfries*, gave up public teaching; but Dr. Bell was continued ſome time longer in his family, as a private pupil. Under the care of this excellent ſcholar, he had great advantages. At the time he left him, which was before the completion of his fifteenth year, he had obtained a perfect acquaintance with the Roman claſſics, a competent knowledge of Greek, he was initiated in the French language, was well ſkilled in geography, hiſtory, and the elements of mathematics, and had commenced a critic in the Engliſh Belles Lettres.

In the autumn of the year 1770, he was ſent to the univerſity of *Glaſgow*, where he continued for one ſeſſion, in the purſuits of general ſtudy. In the latter end of 1771, he was removed to *Edinburgh*, and began his profeſſional ſtudies under the care and direction of his friend and relation Mr. *Benjamin Bell*, whoſe name is now well known in the medical world. At this univerſity he continued till the ſummer of the year 1777, when he obtained the degree of Doctor of Medicine, and publiſhed the Inaugural Diſſertation, to which you are about to give a place in your records. During this long period, Dr. Bell had time to apply himſelf, not only to the various

ous branches of medicine, but to the different departments of philoſophy and polite literature, neceſſary to a plan of liberal and general education. As his application was great, his acquirements were very conſiderable; and he was ſo happy as to attract the notice of ſeveral perſons eminent for ſcience and learning. Of this number, was the preſent learned Profeſſor of Botany in *Edinburgh*, Dr. Hope, who early diſcovered his acute and enterprizing genius, and diſtinguiſhed him by his patronage and counſel. Of this number likewiſe was the celebrated Dr. *Cullen*, who honoured him with his particular friendſhip, and introduced him to the late Lord *Kames*, in a manner which was extremely flattering. His Lordſhip, when engaged in the compoſition of the work, which he afterwards publiſhed under the title of, THE GENTLEMAN FARMER; applied to Dr. *Cullen* for information on ſome ſubjects connected with the philoſophy of vegetation. The learned profeſſor, being deeply engaged with other ſubjects, referred him to Dr. Bell, then in his twentieth year, whom, on that occaſion, he introduced to his Lordſhip. An acquaintance, thus begun, was matured into intimacy, and Dr. Bell ſpent a conſiderable part of one or two autumn vacations at the country ſeat of this venerable old man, in the ſouth of *Scotland*. Lord Kames mentioned him with honour, in the

the work to which I have alluded, and entertained a particular regard for him to the end of his life. When he made the tour of *France*, the letters of introduction, which he procured from this illustrious philosopher, were of the greatest service; and he was likewise much indebted to his friendship, when he afterwards settled as a physician at Berwick on Tweed.

While Dr. Bell was pursuing his studies at *Edinburgh*, his elder brother, to whose most affectionate care he was highly indebted, met an untimely and unexpected fate. In the autumn of the year 1776, he perished in bathing in the river Kirtle, near the bottom of his own garden. This admirable young man was bred to the Scotch law. His talents and his virtues made his life most honourable, and his early death most deeply lamented.

Soon after his graduation, Dr. Bell removed from *Edinburgh* to *London*, with the view of completing his education, and after a winter's residence there, he passed over into *France*. At this time, he relaxed from the severity of his studies, and mingled more than might, from his former habits, have been expected, in the scenes of gaiety and pleasure with which *Paris* abounds.

In the latter end of the year 1778, he returned to *Scotland*. Some part of that, and the succeeding winter, he spent in *Edinburgh*, and, during

the reſt of his time, he in general lived with his mother and ſiſters at his paternal eſtate. While there, beſides the gratis exerciſe of his profeſſion among his friends and neighbours, he was much engaged in the ſtudy of the French and Roman claſſics, and particularly, of the works of *Virgil*, of whom he was an enthuſiaſtic admirer. In this interval, he compoſed two MSS. volumes of criticiſm on the *Æ*neid.

In the ſpring of the year 1780, he ſettled, as a phyſician, at Berwick on Tweed, with very general and powerful recommendations; and, in leſs than a year, he fell into the firſt practice in that quarter. But, it having been repreſented to him, that he might have a larger field for the exerciſe of his profeſſional talents at *Mancheſter*, he removed thither in the month of March 1781.

It is not neceſſary to detail the incidents of the remaining part of his life. On this ſubject you cannot want information. He was admitted as a member into your Society, ſoon after his arrival in *Mancheſter*, and he continued ſuch till his death. During this period, you all, probably, knew him, and it becomes you, better than me, to eſtimate the degree of regard and eſteem, with which he was honoured. It only remains, that I give a ſhort account of the concluding ſcene, to which, by the privilege of friendſhip, I was a mournful witneſs, and on which

which I reflect, with mingled fenfations of pain and pleafure, which I forbear to defcribe.

On the 20th of laft January, he was feized with the fymptoms of a fever, which, from the firft, he apprehended would prove fatal. He requefted the advice of his friends Dr. *Manwaring* and Dr. *Percival*, and they attended him, through the whole illnefs, with the utmoft kindnefs and affiduity. But, notwithftanding every affiftance which medicine could bring, the difeafe proceeded with moft unfavourable omens. He clearly forefaw his approaching fate, and prepared for the moment of diffolution, with unfhaken fortitude. On the eighth day he became delirious; and from this time forwards he poffeffed his reafon, by intervals only. A vigorous conftitution fupported him, under a violent difeafe, till the evening of the fourteenth day, when, after having fuftained many fevere conflicts, his ftrength became utterly exhaufted, and he expired without a ftruggle.—In this manner was terminated the life of a man, who had virtues to procure the love, and talents to command the refpect, of his fellow-creatures; and who, by an affecting, though not uncommon, difpenfation of Providence, was cut off in the beginning of his career.

Dr. Bell was endued by nature with a firm undaunted mind, a vigorous underftanding, and a feeling heart. All his impreffions were ftrong,

 and

and his convictions deeply rooted. From these, and from these only, he spoke and acted. He was utterly free from every species of dissimulation or deceit. His conduct was always direct, and his purpose evident. His deliberations were more swayed by what he himself thought right, than by what was likely to be thought right by others; and when his determination was once made, he was not easily diverted from it, either by fear or favour. His adherence to truth was strict and uniform, even from his early youth. His spirit was too elevated to submit to falsehood, from whatever source it might be supposed to arise, whether from the suggestions of vanity, the impressions of fear, or the dictates of malice. His humanity was pure and unaffected. No man did a kind action with less consciousness of merit, or less purpose of gaining applause. His passions were warm, his affections strong, his sense of honour nice, his spirit, when provoked, high and indignant. In the more intimate relations of life, he was greatly beloved; in many of the qualities necessary for friendship, he has seldom been equalled. Through the whole of his conduct there appeared a strain of manly sincerity. From his cradle to his grave, he, perhaps, never, on any one occasion, sacrificed reality to appearances, or courted applause from others, which was not justified by the approbation of his own heart.

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Theſe high endowments do not often appear without their kindred defects. A fearleſs temper, and an open heart, are ſeldom ſtrictly allied to prudence, and are apt to inſpire a contempt of appearances, which may have ſerious conſequences in the buſineſs of life. That this was inſtanced in Dr. Bell, thoſe who loved him beſt are forced to allow. He was not always ſufficiently attentive to the decorum of manners: he was too much diſpoſed to break through thoſe reſtraints, which a neceſſary ceremony has impoſed on the intercourſe of ſociety. Free from affectation himſelf, he was quick in diſcerning it in others; and he ſeldom allowed any thing which bore its reſemblance, to paſs unnoticed, even in thoſe for whom he entertained the higheſt eſteem. The conſequence which vanity often aſſumes, and which benevolence ſees and admits, he was too much inclined to expoſe. This bias of mind appeared before he was eight years of age. At that time, the uncommon livelineſs of his temper, and quickneſs of his apprehenſion, made him univerſally admired, as a child of extraordinary talents. Every ſally of his imagination was encouraged, and the diſpoſition to which I have alluded, grew up into a habit, which great tenderneſs of heart and ſtrength of judgment could never effectually overcome. The features of his character were indeed ſtrongly marked throughout, from his early

youth. When yet a boy, he had the ſame independence of ſpirit and originality of mind, which marked his riper years.

Failings, ſuch as his, have their moſt unfavourable effects in general intercourſe. In the eye of friendſhip they appear of little account, when weighed againſt a liberal, cultivated, and vigorous mind, and a temper brave, generous, and ſincere.

Dr. Bell acquired knowledge with remarkable facility; but he did not communicate it with equal eaſe. This was chiefly owing to early habits of verbal and grammatical criticiſm, in which he had greatly indulged. He was extremely nice in his choice of words; he would uſe no expreſſions that were not exactly fitted to his ideas, and, in his diſlike of every thing ſtrained or affected, he had declared war againſt ſome of the natural ornaments of ſpeech. His reading was extenſive, and his learning various. In every thing which related to his profeſſion, he was minutely informed. His education had afforded him every opportunity of improvement; his application was great, and his acquirements were proportionably valuable. In claſſical literature he had few equals; and, in hiſtorical and philoſophical knowledge, he had not many ſuperiors.

The qualities of Dr. Bell's mind required a ſtate of action. He was eminently fitted for

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ſituations of difficulty or danger; and had his lot been caſt differently, the enthuſiaſm of his ſpirit, and the ſtrength of his faculties, might have enrolled his name in the liſt of thoſe which go down, to future ages, with honour and applauſe. It was his misfortune, that his ſituation did not always preſent objects of ſufficient importance to excite his attention, and call forth his faculties; and that, like many other men of genius, he was often unable to originate thoſe literary exertions, which ſometimes bring fame, and which generally bring happineſs. His ſpirits indeed were not equal. He was often lively, chearful, and familiar, and ſometimes grave, inattentive and reſerved. Circumſtances, which it would be painful and improper to relate, contributed to throw ſome degree of gloom over his latter days. But he was naturally ſubject, at times, to thoſe ebbings of the mind, as an admired writer expreſſes himſelf, which generally accompany great ſenſibility; a ſtate, from which the tranſition is ſometimes more eaſy to levity and mirth, than to the ſober exerciſes of reaſon.

It is common to expect, even in the more minute parts of the conduct of men of allowed ſuperiority of talents, ſome marks of intention and deſign, by which ſuch ſuperiority might be indicated. But this is, I think, an error. The characteriſtic of genius is ſimplicity. A lofty ſpirit ſubmits, with difficulty, to reſtraint or diſ-

guiſe; and the higher emotions of the mind are ſeldom compatible with a nice attention to little things. It is, however, to be lamented, that men of great endowments are often deficient in that ſelf-command, which ſhould give regularity to conduct, and ſteadineſs to exertion. But let us not too haſtily condemn them. The powers of genius impoſe the ſevereſt taſk on the judgment. The imagination, in which they reſide, muſt always be ſtrong; the ſenſibility by which they are attended, muſt often be wayward. To reſtrain, to excite, and to direct, the exertions of a mind ſo conſtituted, according to the dictates of reaſon, muſt frequently produce a moſt painful warfare: and, if to ſucceed in ſuch conteſts be not always given to the ſtrong, let the weak rejoice, that they are ſeldom called to the encounter.

Years and experience would, moſt probably, have remedied, in a great meaſure, the defects in Dr. Bell's character; and, as he became more fully known, it may be preſumed, that he would have acquired a degree of reputation ſuited to his great integrity and abilities. Yet it cannot be denied, that a temper ſo open, and a conduct ſo little affected by the opinions or prejudices of others, were not perfectly calculated for ſucceſs in a world, in which the moſt honeſt heart muſt often be veiled, and the loftieſt ſpirit muſt ſometimes bend.

Such,

Such, Gentlemen, was the man, whofe memory you wifh to preferve in the Records of your Society. I knew him better than any perfon living, and I loved him more than I fhall attempt to exprefs. I have not, however, dealt in unmixed eulogy, which fometimes may amufe the living, but which can never characterife the dead. It belonged to him I have attempted to commemorate, to be as jealous of undeferved praife, as of undeferved cenfure; and I have endeavoured to delineate his character, in fuch a manner, as his magnanimous fpirit would have approved. I have not, knowingly, extenuated his faults; and you will not believe, I have fet down ought in malice. What would it avail me to deviate from the truth? The voice of cenfure cannot pierce the grave, nor flattery footh the ear of death.

J. C.

LIVERPOOL, *September* 30, 1784.

A TRANSLATION

A TRANSLATION *of Dr.* BELL'S THESIS, *de* PHYSIOLOGIA PLANTARUM. *By* JAMES CURRIE, M. D.* *Read March* 30, 1785.

DIFFERENT parts of nature have drawn the attention of different philoſophers. While ſome men of the greateſt genius have employed themſelves in the ſtudy of their own ſpecies; others have been diligently engaged in inveſtigating the properties of the inferior claſſes of animals. Nor are thoſe to be placed in the loweſt claſs of philoſophers, whoſe time and attention are engroſſed by that immenſe portion of nature, the Vegetable Kingdom; though, it is to be regretted that, in general, their obſervations have been directed more to the external form of plants, than to their internal ſtructure.

The knowledge of the internal ſtructure of vegetables unfolds their œconomy, and, from a diſcovery of this, not only botany, but agriculture, might receive great improvement. But this

* The original was publiſhed at Edinburgh, June 1777, and dedicated to doctors CULLEN and HOPE, in language, which expreſſes a high admiration of their talents and virtue, and a deep ſenſe of gratitude for the *favours* received from them, by the AUTHOR.

this subject is as difficult, as it is important, and, as yet, it is not precisely understood, even by the most curious observers. I am led to engage in it more by the pleasing nature of the study, than the hope of surpassing those who have gone before me; and I purpose, in the following Essay, to confine myself to a few remarks on the structure, life, and functions, of vegetables.

It is proper to premise, that if the anatomy of plants be not demonstrated throughout, with all the clearness that could be wished, this arises from their containing parts of such a degree of minuteness, that they elude the human sight. The nature of these must therefore frequently be inferred from analogy only, which is often fallacious. But many things have been ascertained on this subject, and with these I shall begin.

On making a transverse section of a tree, it appears to consist of three distinct parts—the bark—the wood—and the medulla, or pith.

1. The bark consists of two parts—the cuticle, and the true bark. The cuticle of plants affords an external covering to all their parts. It consists of numerous layers, easily separable from each other, and of which the fibres are circular.*

The

* Dr. Hill, by the use of magnifying glasses, first discovered the cuticle to be an organized body, containing longitudinal vessels, and vesicles, &c. He however thought, the cuticle was formed merely by the hardening of the superficies of the true bark, when exposed to the external air.

The true bark may be considered as a congeries of cellular substance, in which are placed two kinds of organs, the vasa propria, or the vessels peculiar to the plants, and the longitudinal fibres. Of the use of these, nothing can be said at present.

2. On removing the bark, the wood appears. Its substance is denser than the bark, and its structure more difficult to be demonstrated. But it has been discovered likewise to contain vasa propria, and longitudinal fibres, and, besides these, large vessels with spiral coats, which run from one end of the tree to the other, and are denominated vasa aëria. Between the wood and the pith lies a green coloured substance, first accurately described by Dr. *John Hill*, and by him affirmed to contain all the parts of the plant in embryo: he gave it the name of Corona.

3. In the centre of the tree resides the pith, which, in young plants, is very abundant. As they approach to maturity it grows drier, and appears in a smaller quantity; and, in very aged trees, it is entirely obliterated. Its substance is cellular, and, according to the author just men-

air. In this he was mistaken, because it is found in the heart of fruits, covering the seed, and because *Du Hamel*, and Dr. *Hope* found, that, when the cuticle is removed, and the accession of the air prevented by wax-cloth, *this* covering is nevertheless in a little while restored.

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tioned, it is of a ſimilar ſtructure in all plants. Theſe are the ſolid parts of vegetables.

But there are likewiſe fluids, or juices in vegetables: and theſe are of two kinds. The one is of the ſame nature in all the variety of vegetables: the other varies according to the different plants in which it exiſts. The former, which is called the *ſuccus communis*, when collected early in the ſpring, from an inciſion made in the birch or vine, differs little from common water.* The latter, which is named the *ſuccus proprius*, poſſeſſes various properties in various plants, and gives to each its ſenſible qualities. Theſe two juices never mingle with each other in the tree, and the latter is found in the *vaſa propria* only.

It is not yet aſcertained, whether the juices of plants are tranſmitted through veſſels, or cellular ſubſtance. Each ſide of the queſtion has had its advocates, who have ſupported their reſpective opinions with probable arguments: but it is to be regretted, that, on ſo

* It has, however, been alledged to contain a ſaccharine matter in ſome trees, as in the maple, &c. It has likewiſe been ſuppoſed to contain an acid. But, in various experiments which Dr. *Bell* made on it, he found nothing in it of either kind; and therefore, where ſuch appearances have taken place, he ſuppoſed them to ariſe from an adventitious mixture of the ſap, and the *ſuccus proprius*. J. C.

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intereſting a ſubject, no concluſion can be formed from the actual diſſection of vegetables. To me it ſeems moſt probable, that all the fluids of plants are tranſmitted through veſſels, for the following reaſons. 1. The exiſtence of *vaſa propria*, and *vaſa aëria*, is diſcoverable by the naked eye, and made ſtill more manifeſt by the microſcope. That *ſuccus proprius* and air are contained in theſe is evident, and therefore analogy leads us to believe, that the *ſuccus communis* is alſo contained in veſſels. 2. Secretion, of which vegetables have undoubtedly the power, is in no inſtance, that we know of, performed without the action of veſſels. 3. An experiment, made by Dr. *Hales*, ſeems clearly to prove, that the ſap is contained within its own veſſels, and does not fortuitouſly pervade every interſtice of the plant. He fixed an inſtrument round the ſtem of a vine, by which its contractions and expanſions could be accurately meaſured; but he found no difference in the circumference of the trunk, when the tree was full of ſap, and when it was entirely without it, although the inſtrument employed was ſo nice, as to detect a variation of the hundredth part of a finger's breadth. If the ſap had been tranſmitted, without veſſels, through the cellular ſubſtance, this, on the withdrawing of the ſap, would have been compreſſed, and

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of courſe the ſtem of the tree would have contracted itſelf into a ſmaller compaſs. *

We are now to conſider in what direction the fluids of plants are tranſmitted.

I. *Of the Courſe of the* Succus Communis, *or* Sap.

Botaniſts have made many experiments to aſcertain the courſe of the ſap. Early in the ſpring, when the ſap begins to flow, inciſions have been made in the trunk and branches of trees, as far as the pith; and, in ſuch caſes, it has been conſtantly found, that a larger quantity of ſap flowed from the ſuperior, than from the inferior margin of the inciſion. This circumſtance led to the opinion, that in the beginning of the ſpring, great quantities of moiſture are abſorbed by trees from the atmoſphere, and hence the ſource of the abundance of ſap.† But this concluſion, I found to diſagree with the phe-

* To determine this queſtion abſolutely, it may ſeem, that the moſt certain and obvious method would be by injections, the great ſource of our knowledge of the anatomy of animals. They have been employed by *Bonnet*, Dr. *Hope*, and others, but they have failed. They riſe a conſiderable way into plants, but as, in different caſes, they take different courſes, from this, and other circumſtances, there is reaſon to believe, that their courſe, and that of the ſap, are materially different from each other. J. C.

† *Duhamel* and others. See Phyſ. des Arbres, Tom. I. p. 67.

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nomena of nature from the two following experiments. 1. Having made inciſions of various heights into the ſtem, of ſeveral plants, I immerſed their roots into a decoction of logwood. The roots abſorbed the coloured liquor, which at length began to flow from the ſuperior, and not from the inferior, margins of the inciſions; nor had the liquor extended itſelf much upwards, beyond the margin of the inciſion from which it was diſcharged.

2. In the ſeaſon when the ſap flows moſt abundantly, called the bleeding ſeaſon, a deep cut was made into the branch of a growing vine, and the greateſt quantity of ſap was diſcharged from the upper margin of the inciſion: but a branch of the ſame tree, cut in the ſame manner, being inverted, the ſap flowed moſt copiouſly from the other margin of the inciſion, which of courſe was now that next the root. On the other hand, many experiments may be brought to prove directly, that, in the bleeding ſeaſon, the ſap aſcends from the roots towards the branches; the following however may ſuffice. 1. Early in the ſpring, when little or no ſap had as yet entered the plant, Dr. *Hope* made a number of inciſions, of different altitudes, into the root and ſtem of a birch. As the ſap roſe, it firſt flowed from the ſuperior margin of the loweſt inciſion, and then, in regular ſucceſſion, from the upper margins of the other inciſions till

till at laſt, it reached the higheſt. 2. If, in the beginning of the bleeding ſeaſon, before the ſap is found in the ſtem or branches, an inciſion be made in the root of a vine, a conſiderable flow of ſap will follow the wound. 3. The quantity of ſap is very generally proportioned to the humidity of the ſoil.*

II. *Of the courſe of the* SUCCUS PROPRIUS.

When a portion of the bark and wood of the pine, is cut from the ſtem, the *ſuccus proprius* flows in conſiderable quantity both from the upper and under margin of the inciſion. Hence it occurred to botaniſts, that this juice might have little or no motion, and that its efflux from ſuch an orifice might depend entirely on its being freed from the preſſure of the bark and wood.

* It may ſtill be aſked, Why the ſap flows moſt from the ſuperior margin of each inciſion, ſuppoſing it to ariſe from the roots? The inciſion, it is ſaid, hurts or deſtroys the energy of the ſap-veſſels for a conſiderable way below, whence the ſap is not propelled upwards, againſt its own weight, and the preſſure of the atmoſphere now admitted. From the divided veſſels, it paſſes by a lateral communication (for there are ſap-veſſels in every direction) into thoſe undivided, and when it has got above the inciſion, it again paſſes laterally into the divided veſſels; and falling downwards, from its own gravity, a want of continuity of veſſels, and the diminiſhed preſſure of the atmoſphere, it flows from the ſuperior margin of the inciſion. J. C.

wood. But I cannot accede to this opinion: for although in the beginning, the *ſuccus proprius* flows from both margins of the inciſion, in a little while, as I have obſerved, it is diſcharged from the ſuperior margin only. This obſervation in itſelf is not however deciſive. For it may be ſuppoſed, that the liquor flows more copiouſly from the ſuperior margin, becauſe the preſſure of the air is leſs upon it, than on the inferior, and becauſe the liquor itſelf is diſpoſed to fall downwards by its gravity, in the ſame manner as the *ſuccus communis*. That I might put this matter out of doubt, I placed the branch of a pine in a horizontal poſition, and another branch I inverted, ſo that its branches were turned towards the earth. In theſe ſituations, I cut a portion of the bark and wood from each, and, in both inſtances, the *ſuccus proprius* flowed only from thoſe margins of the inciſions which were fartheſt from the roots. Hence it appears clearly, that the courſe of this juice, in its veſſels, is never from the roots towards the branches, but always in the contrary direction.*

Beſides the veſſels of the *ſuccus proprius*, and thoſe conveying the ſap, a third kind are found

* From the experiment above recited, it appears, that the flow of the proper juice is not influenced in the ſame degree, as that of the ſap, by an alteration in the poſture of the veſſel from which it iſſues. To what cauſe this is owing does not clearly appear. J. C.

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in vegetables, named air-veſſels, or *vaſa aëria.* Theſe are chiefly ſituated in the wood, leaves, and petals; but are wanting in the bark of trees, and in the herbaceous plants. They are formed by a number of ſmall filaments, ſpirally rolled up, ſo as to form a cavity in the middle. The name of *vaſa aëria* has been given them, becauſe they are empty of liquor, and becauſe a great quantity of air is certainly found in the wood of plants, where theſe veſſels are chiefly placed, and where there is no peculiar organization. They are ſuppoſed to be the inſtruments of reſpiration in vegetables; but in what manner this function is performed, is not clearly underſtood.

I. Some imagine that the air enters the plants by the roots, in a non-elaſtic ſtate, and gradually recovers its elaſticity in its paſſage through them. To this opinion it is objected. 1. That a great number of *vaſa aëria* is found in the roots of trees, where the juice has undergone little or no circulation, and where of courſe little or no air can be ſuppoſed to be evolved. 2. That the roots are very incommodiouſly placed for abſorbing air, being generally ſo deeply buried in the earth, as to be entirely out of its reach.

II. Others ſuppoſe the air is abſorbed by the leaves, and thence carried into the body of the plant. There are indeed many air-veſſels in the

leaves, and these seem necessary for receiving the air evolved by circulation, which at length passes off with the perspirable matter. But if the air were absorbed by the leaves, and descended towards the roots, its motion would be opposite to that of the sap, and, instead of assisting, would obstruct its progress. It is commonly believed, that after the air has entered vegetables, it is expanded or contracted, according to the variations of the temperature of the atmosphere, and in this way assists the ascent or descent of the fluids. To this opinion it may be objected. 1st. That the air-vessels in the roots, where the sap is first put in motion, are so deep seated, that the changes in the heat of the atmosphere cannot affect their temperature. 2. That the common juice ascends, and the proper juice descends, whether the air be hot or cold. 3. That the pressure of the air-vessels on those which contain juice, will not more promote than obstruct the motion of the fluids in a given direction, unless the vessels which include them contained valves, and in this case these fluids could not have a retrograde motion. Let us look for some more probable opinion.

Dr. Hill has demonstrated, that the cuticle of plants is an organized substance, containing vessels. In trees and shrubs, these vessels have an external opening; but in the herbaceous plants this is wanting. Trees and shrubs only are possessed

poſſeſſed of *vaſa aëria*, and, when a plant is placed under the exhauſted receiver of an air-pump, the air enters through the cuticle, and only iſſues from the wood, in which the *vaſa aëria* are ſituated. From theſe circumſtances taken together, and conſidered attentively, we have reaſon to conclude, that the air's proper entrance to the *vaſa aëria* is through theſe cuticular veſſels. Thus, in the early part of the ſpring, the gentle heat expands the mouths of theſe veſſels, before contracted by the winter's cold. Into theſe orifices, the external air ruſhes and preſſes down to the roots. To theſe it gives energy, as it does to the moving fibres of animals; and, by its preſſure, it may aſſiſt in propelling the juices upwards. An additional quantity of air is evolved by the internal motions of the plant, and the whole paſſes off with the perſpirable matter. In this way, there ſeems to be a circulation of air through plants, aſſiſting and aſſiſted by the powers which move the juices.

The two following facts confirm the above opinion, and, at the ſame time, ſhew, that in plants, as well as animals, impeded reſpiration impedes the motion of the fluids, and interrupted reſpiration deſtroys it.

1. In the winter ſeaſon, I covered ſeveral young trees with varniſh, and at the ſame time wrapt them in wax-cloth, leaving the tops of the

the branches only expoſed to the air. They remained in this ſituation during the following ſummer, when ſome of them lived, though in a languid ſtate, and put out a few leaves; but thoſe from which the air had been more accurately excluded, died without a ſingle exception. 2. Trees over-grown with moſs have few leaves, weak ſhoots, and no fruit. The practice of gardeners is therefore to be commended, who, in the ſpring, ſtrip the moſs from the bark of aged trees, and thus admitting the acceſſion of the air, reſtore them to verdure and fruitfulneſs.

Having conſidered the courſe of the fluids in vegetables, we next proceed to examine the powers by which theſe fluids are moved.

Capillary attraction has generally been accounted the cauſe of the motion of the juices of plants; and the permanence of the action of this power has been ſuppoſed to depend on the evaporation from the leaves. Of late years, indeed, botaniſts have aſcribed to plants a vital power, which they believe aſſiſts the flow of the juices; and to this opinion I accede, for the following reaſons. 1. The deſcent of the juices, that is, their return from the branches to the roots, cannot be explained without the ſuppoſition of a vital power regulating the motion. A flow of fluids, through capillary tubes, will only take place, when the reſiſtance, at the one end, is diminiſhed. This might account for

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the riſing of the ſap, when warmth is applied to the leaves, but cannot account for its deſcending in the ſame circumſtances, that is, when the atmoſphere is warmer than the earth. But this takes place conſtantly, with reſpect to the *ſuccus proprius*, and it is probable, that part of the ſap has the ſame courſe, both in the day and night. 2. The exertions of many plants, on the application of ſtimuli, afford another argument in ſupport of their muſcular power, and the ſpontaneous motions of other plants confirm the ſame opinion. 3. Light admitted to plants, increaſes their perſpiration, and cauſes a leaf, before inverted, to reſume its natural poſition.* The influence of darkneſs contraſts theſe effects, and it produces, what is called, ſleep in plants, although the heat of the atmoſphere be not diminiſhed. Theſe facts ſeem to prove the irritability, or muſcular power of vegetables. 4. If the fluids of plants are conveyed through veſſels, as I have already rendered it probable they are, can we ſuppoſe theſe tubes to be of ſo ſmall a diameter, as, by capillary attraction alone, to raiſe the juices from the roots to the ſummits of the loftieſt trees? 5. On the ſuppoſition of the fluids being moved entirely by capillary

* *Miller* in the Philoſophical Tranſactions, and *Bonnet*, Sur l' uſage des feuilles.

attraction, how happens it, that the fap of the vine flows from an incifion made in the fpring, and not from one made in fummer? In this cafe, as the veffels remain the fame, and the heat is at leaft not diminifhed, the efflux of fap ought to be equally copious in fummer as in fpring. 6. Capillary tubes, filled with liquor, do not difcharge their contents when broken acrofs. But from the ftem of a vine, cut tranfverfely, a large quantity of fluids is difcharged, as has been demonftrated by Dr. *Hales.* 7. The analogy between vegetables and animals, which was formerly pointed out, gives a reafonable prefumption, that the fluids of both are moved by fimilar powers. In animals, the powers of circulation are refpiration and mufcular action: of thofe powers in plants we have already treated, and what has been faid on the fubject, feems to fhew, that the motion of the juices in plants is rather to be afcribed to them, than to capillary attraction.

I might draw fome arguments, in addition to thefe, from fome experiments I have lately made, to afcertain the effects of air impregnated with various effluvia, of light, and of faline folutions, on the growth and qualities of vegetables; but thefe, being as yet incomplete, I forbear to detail. In general, however, it appeared, that there are particular fubftances which

which increaſe the growth of plants, by acting as ſtimuli on their moving fibres.*

There are ſome other functions which belong to vegetables, of which I ſhall now endeavour to give ſome account.

Plants, as well as animals, perſpire, and, in both caſes, this function is eſſential to health. By the experiments of Dr. *Hales*,† and M. *Guettard*,‡ it appears, that the perſpirable matter of vegetables differs in no reſpect from pure water, excepting that it becomes rather ſooner putrid. The quantity perſpired varies, according to the extent of the ſurface from which it is emitted, the temperature of the air, the time of the day, and the humidity of the atmoſphere. As the leaves form the greateſt part of the ſurface,

* The experiments here alluded to were made, to determine the influence of light, of fixed air, of inflammable air, and of the vapour which ariſes from the putrefaction of cabbage leaves, on the growth of vegetables. Dr. *Bell* likewiſe tried the effects of ſome ſaline bodies, of which I do not recollect the particulars. When the different vapours were applied to growing vegetables, the light was accurately excluded. Nevertheleſs, in that to which fixed air was applied, there was ſome degree of taſte and ſmell; and where the inflammable air was uſed, there was likewiſe a tinge of the natural colour. He often thought of repeating theſe experiments, but death prevented this, and many other ſchemes. J. C.

† Statical Eſſays, vol. I. p. 49.

‡ Mem. de l'Academie des Sciences, 1748.

ſurface, it is natural to ſuppoſe, that the quantity of theſe will very materially affect the quantity of the perſpiration. Accordingly, the experiments of Dr. *Hales* have aſcertained, that the perſpiration of vegetables is increaſed or diminiſhed, chiefly, in proportion to the increaſe or diminution of their foliage.* The degree of heat in which the plant was kept, according to the ſame author, varied the quantity of matter perſpired; this being greater, in proportion to the greater heat of the ſurrounding atmoſphere. The degree of light has likewiſe conſiderable influence in this reſpect: for Mr. *Philip Miller*'s experiments prove, that plants uniformly perſpire moſt in the forenoon, though the temperature of the air, in which they are placed, ſhould be unvaried. Mr. *Guettard* likewiſe informs us, that a plant, expoſed to the rays of the ſun, has its perſpiration increaſed to a much greater degree, than if it had been expoſed to the ſame heat, under the ſhade. Finally, the perſpiration of vegetables is increaſed in proportion as the atmoſphere is dry, or in other words, diminiſhed in proportion as the atmoſphere is humid.

The more vigorous and healthy the plant, the more copious the perſpiration; this function, like the reſt, depending much on the vital energy. Exceſſive perſpiration ſeems to hurt,

* Statical Eſſays, vol. I, p. 29.

and

and even sometimes to destroy vegetables; defective perspiration is equally injurious. It is also found, that this function is performed chiefly, if not altogether, by the leaves and young shoots. That it may be properly carried on, all leaves are deciduous; in those trees, called ever-greens, there being a constant succession of leaves, to prevent the organ of perspiration from becoming rigid.

Dr. Hales first observed, that a quantity of moisture is absorbed by plants when exposed to a humid atmosphere. This absorption, as well as the perspiration, is performed by the leaves; but in what manner has not yet been ascertained. Experiments made by *M. Guettard** shew, that perspiration is more considerable from the upper, than from the under, surface of leaves, and those of the same author, of *Duhamel*,† and *Bonnet*,‡ demonstrate, that absorption, on the contrary, is much greater at the inferior surface than at the superior. To prove this, the superior surface of one leaf, and the inferior surface of another, were covered with varnish, and the consequence was, that the former, in a given time, suffered little diminution of weight, but the latter became much lighter. Again, similar leaves

* Memoires de l'Acad. des Sciences, 1749.

† Phys. des Arbres, Tom. I. p. 158.

‡ Traité des feuilles, Mem. I.

were

were laid upon a ſurface of water, and it followed, that thoſe which had their ſuperior ſurface inverted gained little weight, and for the moſt part died in a few days; while ſuch as had their inferior ſurface applied to the water became much heavier, and flouriſhed many months. Theſe facts make it evident, that perſpiration, and abſorption, are not performed by the ſame veſſels, but that each has its peculiar organs.

It has been commonly ſuppoſed, that perſpiration takes place, chiefly, when the air is warm; and abſorption, on the other hand, when it is cold and moiſt. But unleſs the veſſels, peculiar to abſorption, which are placed in the under ſurface of the leaves, were kept conſtantly in action, they would neceſſarily collapſe or decay. All abſorbing organs have a peculiar ſtructure, and an action depending on life: that ſuch an organization is preſent in the leaves of plants, it is reaſonable to conclude, becauſe dried leaves do not abſorb. The ſame reaſoning is applicable to the abſorption performed by the roots: for when a ſmall portion of the root of a hyacinth, growing in water, is cut off, the whole root dies, and new roots are ſhot out, having their extremities peculiarly adapted to the abſorption of nouriſhment.

The noxious matter, carried off by perſpiration, requires large dilution to prevent its hurting the delicate ſtructure of the leaves, and in this

this ſtate accordingly it is thrown out on their ſurface. Here the noxious part is excreted, but part of the diluting fluid is reabſorbed, to ſerve the purpoſe of ſecretion, which could not be performed, unleſs the common juice, or ſap, were previouſly prepared. In the ſame manner, in the animal body, the ſaline and putrid matter, carried off by the urine, muſt be liberally diluted, to prevent it from injuring the tender ſtructure of the kidneys; yet, when it is ſafely lodged in the bladder, a part is reabſorbed, and the groſſer excrementitious matter is alone thrown out. Something of the ſame kind happens in the perſpiration of animals. They certainly take in ſomething uſeful from the ſurface of their bodies, and this is probably performed by veſſels opening outwards, different from the common exhalents. The great quantity of water, abſorbed during the uſe of the pediluvium, and that ſingular ſymptom in diabetes, of the patient's voiding a much greater quantity of urine, than there is liquor taken in by the mouth, ſeem to confirm this aſſertion.

Neither in plants, nor in animals, can we meaſure the exact quantity perſpired or abſorbed, we can only aſcertain the exceſs of the one over the other. For example, if a heliotropium, or ſun-flower, in one day loſe twenty ounces of its weight, in another loſe nothing, and in a third gain in weight ten ounces, it is only thence to

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be concluded, that ſometimes the quantity perſpired exceeds, ſometimes it equals, and ſometimes it is leſs than, the quantity abſorbed.

Plants are poſſeſſed of a power of forming their different parts, and this is done by ſecretion. We may conjecture what the agents are which produce this effect, but in reſpect to the manner of their operation, we are entirely in the dark. In animals, where the vital power is ſtrong, this is the principal agent in producing the new arrangement of parts, which is made in every ſecretion; but in plants, where this power is weaker, it would be unequal to perform the function, if it were not aſſiſted by abſorption and fermentation. Wherever any firm matter is to be ſecreted, the veſſels have a convoluted courſe, to allow the juice to be fermented, and the thinner parts to be abſorbed. In this manner, the ſtones and kernels of fruits are ſupplied with nouriſhment by fibres, which are much convoluted. The proper juice ſeems to be formed only when the ſap has aſcended towards the leaves, and is deſcending to the roots. The wood alſo is formed during the deſcent of the ſap; for when a ligature is made round the ſtem of a tree, the wood above the ligature becomes much thicker, while that below, remains of its former ſize.

The pabula, from which vegetables receive the matter of ſecretion, are contained in the ſurround-

ſurrounding elements. They are chiefly nouriſhed by the water they draw from the ſoil; but ſomewhat they likewiſe derive from the light of the ſun, on which their ſenſible qualities principally depend. On this ſubject I have likewiſe made ſome experiments, but not with that degree of exactneſs, which ſhould enable me to lay them before the public.

Some botaniſts have conceived, that plants, as well as animals, have a regular circulation of their fluids. Others think this very improbable. On both ſides, recourſe has been had to experiments; and from theſe, concluſions perfectly oppoſite have been deduced. When a ligature has been fixed round a tree, in ſuch a manner, that no juice could be tranſmitted through the bark, the tree has been found to thicken above the ligature; but below it, to continue of the ſame circumference. Hence ſome have concluded, that the ſap aſcends through the wood, and deſcends through the bark. Thoſe who are of a contrary opinion have found, that, in certain caſes, the juice aſcends through the bark only: for when a portion of the wood has been cut out, and the bark exactly replaced, the growth of the tree has been found to go on unchanged: hence it is ſaid, that the juice is tranſmitted equally through all parts of vegetables. The experiments adduced on each ſide of the queſtion are

are juſt, but the reaſonings on theſe, by each party, ſeem equally inconcluſive. The analogy of animal nature appears to favour the opinion, that the juice riſes through the wood only, and deſcends only through the bark; but this analogy is not complete throughout. The arteries are not placed in the internal parts alone, nor the veins in the external, but they accompany each other through every part of their diſtribution. In vegetables, the ſap riſes *from* the roots, but the proper juice deſcends *towards* them; in the deſcent of the juice, the wood acquires its growth, and abſorption is a conſtant action of the leaves. Theſe obſervations render it probable, that there is a circulation of the juices; and if there be, the veſſels which perform it, we may reaſonably believe, accompany each other through every part of their courſe.

On the whole we may conclude, that the formation and growth of the parts of plants, depend, chiefly, on the vital energy, which is not however exerted, except on the application of ſtimuli.* We admire the marks of wiſdom and deſign, which appear in the creation and preſervation of vegetables, but we have no reaſon to believe

* Dr. *Bell* from ſeveral experiments to which he has alluded, was of opinion, that many of the manures produce their effects by acting as *ſtimuli* on the moving fibres of vegetables. J. C.

that

that they are poſſeſſed of any intelligent power, which preſides over and directs their peculiar functions.

Both plants and animals are, from their conſtruction, much under the influence of ſtimuli, and all organized beings are regulated more by general, than particular, laws.

The principle of life ſeems univerſally diffuſed through nature, but beſtowed on different beings in different degrees. To animals is given the largeſt ſhare; but throughout the whole animal kingdom, one ſpecies deſcends below another in the perfection of its mental powers, as well as of its organic ſenſations. And this progreſſion is ſo very gradual, that the moſt perfect, of an inferior ſpecies, approaches very near to the moſt imperfect, of that which is above it. The chain is continued between vegetables and animals. Both have the power of propagating their ſpecies, and their modes of procreation are ſimilar. In the lower claſſes of animals, the powers of ſenſe and motion are very indiſtinct. The coral and the water polypus adhere to rocks, as plants to the earth; and, like theſe, die on being ſevered from the place where they grew. There are likewiſe plants, which in many things reſemble animals. The Burrhum Chundalli, lately brought from the *Eaſt Indies*, poſſeſſes a living principle, which diſcovers itſelf in the ſpontaneous, and almoſt conſtant motion of its

leaves. The *Sensitiva Mimosa*, and *Muscipula Dionæa*, shew wonderful activity on the slightest impressions, and take the flies and other insects prisoners, by the contraction of their leaves. That these plants *live*, will be granted; but I suspect, that they likewise *feel* I doubt whether we are right, in confining the capacity of pleasure and pain to the animal kingdom. This I may affirm, that some circumstances, common to the generation of plants and animals, and many similarities in their functions and structure, would lead us to the opinion, that sensation likewise is bestowed on both. † It is vain to attempt to establish absolute rules, by which plants may be distinguished from animals, in every case whatsoever. There are animals, which grow to a spot, and, like plants, are nourished by the pores of the skin. And there are plants, which surpass some animals in vital power, and, perhaps, in sensation.

Wherever the principle of life exists, there is a peculiar organization; and as much mechanism is necessary to the structure of a vegetable, as of a human being. This view of the life of vegetables raises botany to the rank of philosophy:

† The excellent professor of botany in *Edinburgh*, Dr. Hope, in his course of lectures, used to speak of Dr. *Bell* with the highest esteem: but did not approve of the idea here thrown out, that plants possess feeling, or perception. J. C.

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it adds fresh beauty to the parterre, and gives new dignity to the forest.

It only remains, that I excuse myself for writing on a botanical subject, when I am a candidate for medical honours. A few words will suffice. Such is the analogy between vegetables and animals, that the knowledge of the nature of the one illustrates that of the other: and as vegetables, in every part of the world, form a great part of our food, as well as of our medicines, it is highly important for every physician to be well acquainted with their nature.

Some Observations *on the* Phænomena, *which take* Place *between* Oil *and* Water, *in a* Letter *to* Thomas Percival, M.D. F.R.S. *and* S. A. *&c. By* Martin Wall, M. D. *Prælector of Chemistry in the University of Oxford.* *Read Nov.* 17, 1784.

DEAR SIR,

THE action of bodies on each other, the principles upon which that action depends, and the causes, which under certain circumstances diminish, impede, or prevent it, have

deſervedly occupied no ſmall ſhare of the attention of philoſophers; becauſe on the knowledge of theſe principles, depend, not merely a curious ſcience, but very many of the neceſſary arts of life. In the earlieſt periods of philoſophy, little progreſs was made in this inveſtigation. Some crude conjectures were advanced concerning peculiar emanations, &c. which, having no foundation in experiment, were as quickly rejected as they had been formed. The patrons of the corpuſcular philoſophy imputed the influence of bodies on each other, or the defect of ſuch influence, to the peculiar forms of their original particles; and the mechanic ſect ſuperadded to this ſyſtem the doctrine of attraction. The theory which depends upon the form of the conſtituent particles of bodies, is very weak and unſatisfactory, and, if it has not been abſolutely confuted by experiments, has certainly received no confirmation from them. But the grand principle of attraction, has, by the cleareſt evidence of concluſive facts, received the moſt ample confirmation, its laws have been explained, and the univerſal extent of its operation has been ſo fully demonſtrated, that *Bergman* was perfectly juſtified in ſpeaking of it, as the principal agent in every operation, grand or minute, in the ſyſtem of the world, "cui omnia in globo noſtro obedire videntur."

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The action, however, of this great agent is not ſimple and uniform: it admits of great variation, and operates by different laws, as we ſee in the different phænomena of gravitation, of coheſion, of electricity, of magnetiſm, and of chemical affinity. Thus, in our electrical and magnetical experiments, we have frequent occaſion to obſerve, that the ſame bodies which are attracted by one are repelled by a third, and *inter ſe*, as the circumſtances of the experiment are varied. Perhaps, ſomething of the ſame kind may limit or impede the attraction of gravitation and coheſion, in particular caſes. Hence philoſophers have ſuppoſed another principle of nature, oppoſite to that of attraction, which they have denominated *repulſion*, and have imagined the influence of this principle to begin, where that of attraction ends. The obſervations deduced from the phænomena above alluded to, have been transferred alſo to chemiſtry; and becauſe certain bodies ſhew no diſpoſition to form a chemical union, they have been ſaid to poſſeſs a *repulſive* faculty with reſpect to each other. To ſay, that a principle of repulſion has no exiſtence in nature, would be too preſumptuous: but I am inclined to believe, that the ſpecies of attraction, which conſtitutes chemical affinity, is not counteracted by any principle of repulſion in thoſe caſes, where no affinity appears to take place; and that the apparent

repulſion depends upon a perfectly different cauſe. To purſue this doctrine through all thoſe inſtances of chemical ſubjects, which ſhew no diſpoſition to unite, would be almoſt endleſs; but that I may give it a little illuſtration, permit me to draw your attention to one example.

One of the moſt common examples adduced of this repulſion, is, the immiſcibility of oil with water, which cannot be effected without ſome intermedium. But what is here called repulſion, is perhaps, only a caſe of that kind which is called elective attraction (if I may be allowed to adopt that expreſſion); that is, that the particles of water attract thoſe of water, and the particles of oil thoſe of oil, more ſtrongly than oil attracts water; and, therefore, when theſe are mixed or brought into contact, no new or more powerful attraction taking place, both ingredients continue diſtinct and diſunited: and it is upon the ſame account, that when one of theſe fluids is *inveloped* in the other, it is diſpoſed to form itſelf into one or more ſpherules from the ſtrong attraction of its particles *inter ſe*.

The principle thus laid down will receive illuſtration from, and at the ſame time will aſſiſt to explain, ſome phænomena reſulting from the immiſcibility of oil and water, which, though well known, have not been much regarded in a philoſophical point of view. The facts, to which I particularly allude, are, the effect of

oil

oil and oily ſubſtances in preventing the cryſtallization of ſalts, and in ſmoothing the waters of the ſea, &c. when agitated by winds.

The general proceſs for making common ſalt at *Droitwich*, we are told, by Dr. *Naſh* in his Hiſtory of Worceſterſhire, is, firſt to put a little common water into the pan to keep the brine from burning to the bottom: the pan is then filled with brine, and a piece of reſin about the ſize of a pea thrown in to make it granulate fine. I doubted, he adds, the reſin's having any ſuch power, but am aſſured by Mr. Romney, a principal and obſervant proprietor, that the more reſin they uſe, the finer will be the grain of the ſalt; and if a lump of the ſize of two walnuts were put into the pan, the grain would be ſo fine as not to ſubſide at all. (*Naſh*'s Hiſt. of Worceſterſhire, vol. I. p. 300.) The ſame effect, which is here aſcribed to reſin, may be obtained by the uſe of butter, tallow, and any other oily matter, which will liquefy by the heat uſed in boiling the brine, and, when ſo liquefied, is incapable of mixing with the water. In conſequence of this, it forms a thin film upon the ſurface, greater in proportion to the quantity uſed.

To the perfect cryſtallization of ſalts, it is required, that the water which holds them in ſolution be ſlowly evaporated, and that the ſurface be extenſive, quite open, and expoſed to the

free acceſs of air, becauſe air is requiſite to the formation, and, perhaps, as well as water makes a conſtituent part of every perfect cryſtal. If the ſurface of the water have not a free communication with the air, and the boiling be carried on rapidly, the ſalt falls down in ſmall granules, and no cryſtals are formed. This appears to me to be the effect of the thin oily film in the proceſs above deſcribed, which is explicable upon the principles formerly advanced.

Of the effect of oil in ſmoothing troubled waters, ſo full an account is given by Dr. *Franklin*, in the Philoſophical Tranſactions for 1775, that it is not neceſſary to be particular as to the matter of fact, which is now generally known. I think this fact alſo is eaſily explicable upon the principles, which I have laid down, viz. that the particles of oil have a ſtronger attraction for each other (or *inter ſe*,) than they have for water, and probably, than they have for air. Air, we know, has a conſiderable attraction to water, ſo that the one is ſeldom free from the other, and, when they are brought into contact, they ſeem to unite and adhere by the double force of chemical affinity and mechanical coheſion. Therefore, when a conſiderable body of air is forcibly impelled, as in a ſtorm, upon the ſurface of water, it in a manner *lays hold* of the water, carrying or forcing

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it along with it in its courſe, until the water, reacting by its gravity, returns forcibly to repair its level; and by this repeated impulſe and reaction, the ſurface of the water undergoes that violent agitation, which conſtitutes a ſtorm. But if oil be thrown on the ſurface of the water, it ſpreads itſelf over it to a conſiderable extent, and the wind is prevented from *laying hold* of the water, but glides ineffectually over it without cauſing any tumult or agitation.

In ſome parts of this illuſtration, I ſhall be found to agree with Dr. *Franklin*, but to differ materially in this, that he aſcribes the ſpreading of the oil on the water to a *repulſive* force, which, with the utmoſt diffidence and deference to his eminent abilities, I am diſpoſed not to admit. I think the principle, which I have laid down, ſufficiently adequate to the explanation of the phænomenon, that the particles of oil have a very ſtrong attraction for each other, and have none at all for water, and probably not for air. The very circumſtance of the oil's ſpreading over the whole ſurface of the water in one uninterrupted film, ſeems to favour my hypotheſis; for, if the particles of oil had a repulſion to water, and at the ſame time a ſtrong attraction *inter ſe*, they would probably not ſpread equally over the ſurface, but form into diſtinct globules, and immediately upon touching the water, would recede from it to the neareſt part of the

margin

margin or ſhore. But, according to my ſuppoſition, when any quantity of oil is poured upon water, being lighter than that water, it will neceſſarily ſwim upon it; and by the common laws of hydroſtatics, it will immediately tend to form an exact horizontal level: in doing this, it will ſpread upon the ſurface of the water, till it forms a film almoſt inconceivably thin, and perfectly unbroken, on account ſolely of the ſtrong attraction of the particles of oil to each other.

I will cloſe theſe obſervations with a few remarks on the ſingular fact, to which I have juſt now alluded.

The world is diſpoſed to call this a diſcovery of Dr. *Franklin*; but in that they are much miſtaken. He himſelf does not pretend to claim the diſcovery of this fact; nay, he produces many proofs, that it was well known and applied long ago. It requires, however, very frequently the name of an ingenious man to perſuade us to take notice of a very common phænomenon; for this ſingular operation of oil, though it excited ſo much attention, as a novelty, when introduced by Dr. *Franklin*, was long ago remarked by naturaliſts much leſs informed than thoſe of modern times. Of this I ſhall mention a few inſtances, in addition to thoſe alluded to by Dr. *Franklin*. *Pliny* ſays of the ſea, " Anne Oleo tranquillari, & ob id urinantes ore ſpargere; quoniam

quoniam mitiget naturam aſperam, lucemque deportet." *Plutarch* propoſes as one of his natural queſtions, Δια τι της θαλαττης ελαιῳ καταρραινομενης γινεται καταφανεια και γαληνη; "Why does the ſea, when ſprinkled with oil, become more ſerene and tranſparent?"

We find alſo, that the knowledge of this effect of oil was common in the earlieſt ages after the revival of learning, from a curious paſſage in the *Naufragium* of *Eraſmus*; "Non nulli," ſays he, ſpeaking of the various efforts of the ſailors in the ſtorm, "procumbentes in ſabulas adorabant mare, quicquid erat olei effundentes in undas." A note in the Elzevir edition of Eraſmus' Colloquies, thus illuſtrates the paſſage; "Ea natura eſt olei, ut lucem afferat ac tranquillet omnia, etiam mare, quo non aliud elementum implacabilius."

Nor has this property of oil been conſidered merely as a matter of ſpeculation and amuſement to philoſophers: it has been applied, from time immemorial, by the natives of various and diſtant countries, who could not have learned it from each other, to the moſt important uſe in procuring proviſions; by the fiſhermen on the coaſt of *Provence*, to enable them more readily to ſee the muſcles and other ſhell fiſh under the ſea; by the ſame order of men in the *Tagus*, near *Liſbon*; and by the inhabitants of the *Hebrides*,

even

even the moſt remote of the weſtern iſles, St. *Kilda.*

About fifteen years before the publication of Dr. Franklin's Memoirs, the following paragraph, perhaps copied from ſome London Newſpaper, was inſerted in the Annual Regiſter. "It has been remarked, it is ſaid, that the oil ſpilt into the river to prevent the ſpreading of the late dreadful fire in Thames ſtreet, viſibly quieted the waves thereof. This efficacy of oil, in ſmoothing the ſurface of water, ſeems to have been long known. By an ancient law, when goods were to be thrown overboard to lighten the ſhip in ſtormy weather, if there happened to be any oil on board, and it could be come at, it was to go firſt; and the Raguſians at this day, when they go a fiſh-ſpearing, throw oil upon the water with a ſprinkling bruſh, and thereby obtain a clear proſpect of the bottom. The openings thus formed by the drops they expreſsly call *windows.*"

By all theſe obſervations, it will appear, that Dr. Franklin cannot be called the diſcoverer of this fact: but ſtill the philoſophical world is greatly indebted to the ardour and zeal, with which he proſecuted his inquiry and experiments, which enabled him to give ſo ingenious an illuſtration of the phænomenon.

FACTS *and* QUERIES *relative to* ATTRACTION *and* REPULSION. *By* THOMAS PERCIVAL, M.D. *&c.*

To the LITERARY *and* PHILOSOPHICAL SOCIETY.

MANCHESTER, DEC. 5, 1784.

I COMMUNICATED to you, a few weeks ago, ſome curious and valuable obſervations, on the phenomena which take place between oil and water, tranſmitted to me by my learned and very ingenious friend Dr. Wall, of Oxford. My engagements deprived me of the pleaſure and inſtruction, of attending their diſcuſſion in the ſociety: And, ſolicitous to recover what I have loſt, I truſt you will indulge me with permiſſion, to recall your attention to the ſubject, by the recital of a few miſcellaneous facts and enquiries, which the peruſal of that paper ſuggeſted to my mind.

I. If a glaſs tumbler, containing equal parts of water and of oil, in ſuch quantity as to occupy two thirds of it, be ſuſpended by a cord, and ſwung backwards and forwards, the oil will remain perfectly ſmooth and undiſturbed, whilſt the water, below, is in violent commotion. But if the oil be poured out, and its place ſupplied with

with water, the fluid will remain perfectly tranquil, throughout the whole veſſel, although the ſame motion be given to it as before. I have frequently repeated this experiment, and have ſometimes varied it, by ſubſtituting rectified ſpirit of wine, in the place of water. The oil then being the heavier fluid, becomes agitated, whilſt the ſpirit remains at reſt. Dr. Franklin, who firſt noticed this ſingular phenomenon, informs us, that he ſhewed it to a number of ingenious perſons. "Thoſe," ſays he, "who are but "ſlightly acquainted with the principles of "hydroſtatics, &c. are apt to fancy, immedi-"ately, that they underſtand it, and readily "attempt to explain it: But their explanations "have been different, and, to me, not very "intelligible. Others more deeply ſkilled in "thoſe principles, ſeem to wonder at it, and "promiſe to conſider it. And I think it is "worth conſidering. For a new appearance, if "it cannot be explained by our old principles, "may afford us new ones, of uſe perhaps in "explaining ſome other obſcure parts of natural "knowledge."* It is with diffidence, I offer as a conjecture, that the fact, in queſtion, may ariſe from a *repulſive power*, ſubſiſting between the particles of oil and water, and depending poſſibly on the vibrations of that ſubtle æther,

* See Dr. Franklin's Letters and Papers on philoſophical ſubjects, p. 438.

which

which Sir Isaac Newton supposes to pervade all bodies. For, when this æther is excited into motion, by percussion or agitation, its elastic force is augmented, because it becomes denser in the pulses of its vibrations, than in a quiescent state.* But in proposing this hypothesis, I may perhaps be chargeable with the paradoxical opinion of a celebrated French philosopher, M. Fontenelle, who asserts, that if there be more than one way of accounting for any appearances in nature, there is a general presumption, that they proceed from causes, which are least obvious and familiar. I shall not, therefore, at present, enlarge upon this point, as it would anticipate what may be better urged, in our subsequent conversation. But the facts, above recited, furnish a presumption, that the effect of oily substances, on the crystallization of salt, is, in part, owing to a mechanical cause. At Droitwich, it is the practice, as appears by Dr. Wall's quotation from the history of Worcestershire, to throw, into the brine pan, a piece of resin, about the size of a pea, to produce a finer granulation. The more resin they use, the smaller will be the grain of the salt; and if a lump, of the size of two walnuts, were put into the pan, the particles of salt would be so minute as not to be capable

* On the properties of Æther, consult Dr. Bryan Robinson's Works, *passim.*

of

of ſubſiding. Reſin, butter, or tallow, when liquefied by the heat of the boiling brine, float upon its ſurface, and will remain perfectly ſmooth and undiſturbed, whilſt the water, beneath, may be put into ſtrong agitation, by the action of the fire. Such agitation muſt break down the cryſtals of ſalt, as they ſhoot; and conſequently, only ſmall granules will be produced.

II. Every one has experienced the ſuffocating effects of air, loaded with the effluvia of burnt greaſe, or the ſnuff of a lamp. When ſuch fumes are inſpired, there is the ſenſation of a conflict in the lungs, which eſſentially differs from what is felt, on breathing either fixed or inflammable air. And is not the moſt eaſy ſolution of it, to ſuppoſe, that the air quits the oily, to unite with the watery vapours, which are brought into contiguity, by this action of the animal œconomy; and that a ſtrong repulſion ſucceeds? "For, as, in algebra, where "affirmative quantities vaniſh and ceaſe, where "negative ones begin, ſo, in mechanics, where "attraction ceaſes, there a repulſive power ought "to ſucceed," according to the doctrine of Sir Iſaac Newton. It is, alſo, an axiom, laid down by this great philoſopher, that "to the ſame "natural effects, we muſt always aſſign, as "far as poſſible, the ſame cauſes." I ſhall therefore proceed to illuſtrate this ſubject, by other more deciſive examples of *repulſion*; after premiſing

premiſing a few obſervations on that ſpecies of *attraction*, which appears to be the converſe of it.

III. That the particles of homogeneous bodies have an affinity to, and conſequently attract each other, is conſonant both to analogy and obſervation. Fluids manifeſt this property, by their diſpoſition to aſſume a globular figure, and by the ruſhing together of theſe globules, when brought within their reciprocal ſphere of activity. A ſimilar attraction ſubſiſts between heterogeneous ſubſtances, which is diſtinct from that of *cohesion*, as it partakes of an *elective* nature, and yet cannot be deemed *chemical*, becauſe no combination is produced by it, ſo intimate, as to manifeſt any change of properties. This may be illuſtrated by the increaſe of power, in the ſuſpenſion of weights, which a hair acquires, by being moiſtened with different liquids. For ſuch additional ſtrength is not proportioned, preciſely, to the tenacity of the liquid employed; and probably ſubſiſts in a duplicate ratio, compounded of the affinity which the parts of the liquid bear to each other, and to the minuteſt fibres of the hair. The particles of water attract one another more ſtrongly, than they attract poliſhed wood or ſtone; whilſt, on the contrary, they are leſs forcibly attracted by each other than by glaſs. This is evinced by the common experiment with capillary tubes. For the water, which aſcends, muſt have quitted the con-

 tact

tact of the water left behind, contrary to their mutual affinity, as well as to the law of gravitation. The particles of quickfilver, like water, are attracted by glafs. For if a fmall globule of this metal be laid upon unfullied paper, and touched with a piece of clean polifhed glafs, the quickfilver will adhere to the latter, in preference to the former, and may be drawn away with it. But the relation of mercury to glafs is of inferior force, to that which fubfifts between its own particles. This will appear by dipping a bent tube, open at both ends, into a veffel, filled with quickfilver, which will enter into the tube, but ftand within it, below the furface of the mercury, at a depth, proportionate to the diameter of the tube. * It is unneceffary to adduce further inftances of this attraction; and I fhall endeavour to fhew, that where it does not fubfift, a repulfive power apparently takes place. This, according to the laws of optics, has been deduced from the globules of rain, which lie on the leaves of colewort, whofe luftre and mobility are fo ftriking to the eye. For, on a clofe infpection of them, it is found, that the luftre is produced by a copious reflection of light, from their flattened inferior parts. It has alfo been further obferved, that when a drop

* Confult Dr. Jurin's Experiments, Philofophical Tranfactions, No. 363; alfo Cotes's Hydroftatical Lectures, p. 231.

rolls

rolls along a leaf, which has been wetted, its brightneſs diſappears, and the green leaf, before hardly diſcernible, is now ſeen clearly through it. From theſe facts it is inferred, that the globule does not touch the plant; but that it is ſuſpended at ſome diſtance, in the air, by the force of a repulſive power; becauſe there could not be any copious reflection of white light, from its under ſurface, unleſs a real interval ſubſiſted between that ſurface and the plant.* This hypotheſis accounts for the volubility of the drop, and for its leaving no trace of moiſture, where it rolls. From the like reaſoning it hath been concluded, that when a poliſhed needle is made to lie on water, it is not in contact with that fluid, but forms, by repulſion, a bed, whoſe concavity is much larger than its own bulk. Hence it is readily conceived, how the needle ſwims upon a liquid, lighter than itſelf; ſince the quantity of water, diſplaced by it, may be equal to its weight. Can it be philoſophical, to attribute ſuch a phenomenon to the tenacity of water, or to the attraction ſubſiſting between its particles?

IV. The attractions and repulſions between thoſe exhalations that are termed DEW, and certain ſubſtances expoſed to them, are ſtill more remarkable, than the facts which have been

* See Newton's Optics, Query 29. Alſo Phyſical and Literary Eſſays, vol. II. p. 25.

 already

already recited. M. Muſſchenbroek placed different bodies, for the reception of theſe vapours, on the terrace of the obſervatory at Utrecht, and found that ſome caught them abundantly, others only in a ſmall quantity, but that a third ſort repelled them altogether.* M. du Fay, of the French Academy, repeated theſe experiments, and fully proved that, whilſt the dew fell copiouſly into veſſels of glaſs, not the leaſt moiſture was apparent in veſſels of poliſhed metal, contiguous to them. To be aſſured whether the difference was always the ſame, in all circumſtances, between vitrified ſubſtances and metals, he ſet a China ſaucer in the middle of a ſilver plate, and, on one ſide, adjoining to it, put a ſilver veſſel, very like the ſaucer, upon a China plate. The former, viz. the China ſaucer, was covered with dew, although the plate, which ſpread four inches around it, had not a ſingle drop. The China plate, alſo, received the dew, whilſt the ſilver veſſel, that was in the middle, remained as dry, as when it was firſt expoſed.

The ſame ingenious philoſopher endeavoured to aſcertain, whether a China ſaucer, ſet upon a plate of metal, in the manner above deſcribed, did not receive more dew than it would have done, if expoſed quite alone. To accompliſh this deſign, he took two watch cryſtals, of equal

* Introd. ad Philoſ. Nat. vol. II. p. 990.

dimenſions,

dimenſions, and placed the one upon a plate of ſilver, the other upon a plate of China, each with its concavity uppermoſt. That which was upon the ſilver plate, he ſurrounded with a ferrel, of the ſame metal, well poliſhed, that no watery particles might attach themſelves to the convex ſurface of the glaſs. Thus circumſtanced, he expoſed the cryſtals, ſeveral days ſucceſſively, in a proper ſituation, and always found five or ſix times more dew in that, which was on the China plate, than in the other placed on ſilver: And this may be regarded as a preſumptive proof, that the moiſture repelled from the metal, was attracted by the China. That there ſubſiſted ſuch a repulſion, is confirmed by the following obſervation of M. du Fay, with regard to the cryſtal on the ſilver plate. He informs us, that the ſmall quantity of dew on the inſide, was only near the center, in minute drops; and that, round the border, there was a ſpace of five or ſix lines, perfectly dry, towards which the drops regularly decreaſed, in magnitude; as if the ſilver ferrel had *driven away* the dew from that part of the glaſs, which was contiguous to it. Theſe experiments were repeated thirty times, with invariable ſucceſs.* And Dr. Watſon, now Biſhop of Landaff, has lately confirmed them, by ſome very curious trials, of a ſimilar kind, made to determine the quantity of vapours

* Vid. Hiſt. de l'Acad. des Scienc. 1749.

which aſcend, in a given ſpace, from the ſurface of the earth. “ By means of a little bees wax,” ſays he, “ I faſtened a half-crown very near, but “ not quite contiguous to the ſide of the glaſs, “ and ſetting the glaſs, with its mouth down- “ wards, on the graſs, it preſently became “ covered with vapour, except that part of it, “ which was near to the half-crown. Not only “ the half-crown itſelf, was free from vapour, “ but it had hindered any from ſettling on the “ glaſs, which was near it, for there was a little “ ring of glaſs ſurrounding the half-crown, to “ the diſtance of a quarter of an inch, which “ was quite dry, as well as that part of the glaſs, “ which was immediately under the half-crown; “ it ſeemed as if the ſilver had repelled the water “ to that diſtance. A large red wafer had the “ ſame effect as the half-crown; it was neither “ wetted itſelf, nor was the ring of glaſs, con- “ tiguous to it, wetted. A circle of white paper “ produced the ſame effect, ſo did ſeveral other “ ſubſtances, which it would be tedious to “ enumerate.” *

Do not the inſtances of repulſion, here adduced, with various others, which may perhaps be recollected and noticed by the Gentlemen preſent, warrant us to conclude, that this principle is a powerful agent, in the operations of nature? To this cauſe, the air we breathe owes, pro-

* Watſon's Chemical Eſſays, vol. III. p. 64.

bably,

bably, its exiſtence and elaſticity; the light, which illuminates our globe, its rapid motions and diverſified inflections; and fire, its genial, expanſile, and animating energy. Is it, therefore, conſiſtent with analogy, to exclude repulſion from that branch of phyſics, which chemiſtry comprehends? The ſubject certainly merits further inveſtigation: And I ſhall ſtate, to my friend Dr. Wall, the facts and queries, which I have now laid before this Society; that he may communicate to us, ſuch limitations or confirmations of his doctrine, as an attentive review of it may ſuggeſt, to his ingenuous and philoſophic mind.

EXTRACTS *of* TWO LETTERS *from Dr.* WALL *of* OXFORD, *to Dr.* PERCIVAL, *in Reply to the foregoing* QUERIES *concerning* ATTRACTION *and* REPULSION; *communicated to the* LITERARY *and* PHILOSOPHICAL SOCIETY. *Read January* 12, 1785.

DEAR SIR,

IT gives me great pleaſure to think that my paper on oil, &c. was ſo far approved, as to be thought worthy of a place in your Memoirs. I am by no means poſitive, that my hypotheſis

will abſolutely ſtand the teſt of examination, ſo far as to prove, that there is no principle of repulſion in chemiſtry: but I think ſtill, notwithſtanding your very ingenious obſervations, that, in moſt caſes, APPARENT REPULSION may be reſolved into ELECTIVE ATTRACTION. The experiment, which you firſt adduce, made with a mixture of oil and water agitated in a glaſs veſſel, if I underſtand it right, appears to me not to affect the point in queſtion. I think that the commotion, which the water undergoes while the oil remains tranquil, depends upon the different ſpecific gravity of the two fluids (whereby they receive the force of the impulſe in unequal proportions) and upon the diſpoſition of the oil, from its ſuperior levity, to preſerve its place, upon the top of the water, whatever agitation the water beneath may be ſubjected to. In the boiling of brine, I admit that the agitation of the water muſt have a conſiderable effect in breaking down the cryſtals of ſalts, and thus preventing their regular and complete formation: but this cannot be all that takes place, when an oily ſubſtance is put into the brine; becauſe, if it were, the ſame effect would reſult from boiling the brine only without the addition of any oily or reſinous matter.

Forgive me, in the ſecond place, if I ſhould not agree with you in explaining the conflict, which is felt in the lungs, upon the inſpiration of the fumes of burnt oil, in the ſame manner

as

as you do. I think your theory too ſubtile. What is the primary action of atmoſpheric air, received into the lungs; and what appears to be the operation it performs there, before it is reſpired? Do not the late obſervations of innumerable chemiſts ſhew, that it is in part converted into fixed air in that proceſs, and in part phlogiſticated, by carrying off the phlogiſton, ſeparated from the blood in the circulation, and diſcharged by the lungs? The more perfectly the air inſpired is dephlogiſticated, it anſwers the demand of nature more entirely; but when it is either largely mixed with fixed air, or loaded with phlogiſtic particles, ſuch as the empyreumatic vapours from burnt oil, it is rendered unfit for theſe important purpoſes, and, inſtead of carrying off noxious matters, it conveys into the lungs a new cauſe of offence; and thus produces a ſenſe of conflict and uneaſineſs in a two-fold manner; by not carrying off the load from which the conſtitution is uſually freed by the proceſs of reſpiration; and by ſuperadding a *ſtimulus ab extra.*

I cannot admit the application of the laws of mechanical attraction, much leſs the properties of algebraic quantities, to the phænomena of chemiſtry. It was well obſerved by the late excellent Dr. *Lewis*, of Kingſton, in his Philoſophical Commerce of Arts, "that it is of great im-"portance, that theſe two orders or forms of "attraction

" attraction (the mechanical and the chemical)
" should be properly distinguished and separated
" from each other, as many errors have arisen,
" from applying to one, such laws only as obtain
" in the other."

Your illustration of repulsion, from the beautiful appearance of the drops of water on colewort leaves, seems, at first view, to present a most forcible objection to my system; and yet perhaps upon more mature consideration, that fact may be assumed as a confirmation of it. For water, from the strong attraction of its particles to each other, especially when the quantity is inconsiderable, and is allowed to fall upon an inclined surface, does not adhere to that surface, but forms itself into globules, and runs off, till by the breaking of some of the drops, or the accidental *remora* of others, that surface becomes wetted, and then the drops no longer exhibit the property above-mentioned. And this is sometimes remarkable, even when the water falls upon substances, which in other circumstances are much disposed to imbibe it, and to unite with it; as when water is let fall from a height on a surface covered with dust, with flour, &c. And a similar state may obtain upon colewort, and some other large leaves, which are smooth, and are liable, after a dry season, to become covered with the fine dust that floats in the air; or possibly, there exsudes on the surface of such leaves

leaves a resinous farina, or fine oily dew, by which the drops of water falling upon them will be, for some time, prevented from coming into immediate contact with the leaves; but will roll off, formed into spherules by the *intrinsic* attraction of their particles, as quicksilver rolls off from wood, &c.

The phænomena of quicksilver (thus casually mentioned) will indeed greatly illustrate this subject; for that fluid is very remarkable for the strong attraction of its particles *inter se*. You may argue, that mercury, falling upon wood or marble, forms itself into globules upon account of its repulsion from those substances; but if it be allowed to run upon other bodies, to which it has a strong affinity, it displays the same property in various degrees, according as that affinity is more or less strong, more or less powerful to overcome the attraction of its particles *inter se*, and to counteract their disposition to form into globules. Thus mercury, poured upon gold and silver, breaks at first into globules; but these are almost immediately attracted by those metals, lose their mobility, become flat, and, if allowed to continue, amalgamate with the gold or silver: but, poured upon tin or copper, the mercury separates into globules in the same manner, as if it was poured on wood or marble. These globules continue a long time perfect, but at last unite with the tin or copper; because the attraction

attraction of these two metals to mercury is much weaker, than that of the perfect metals, and does not, for some time, overcome the attraction of the mercurial particles *inter se*; therefore the globule preserves its form longer. As I believe it will be admitted by every body, that no repulsive power operates between mercury and either of the four metals, which I have mentioned; I think it will also be admitted, that the phænomena, to which I have alluded concerning them, may be satisfactorily explained upon the principles of my hypothesis. And if this hypothesis applies so well in these instances, it is allowable to extend it to other similar facts, concerning the powerful or weak action of mercury on other metals, and even to transfer it to explain the appearances, which other fluids present in parallel circumstances. From this example then I am induced to conclude, that the attraction of the particles of any fluid *inter se* is the cause, why that fluid forms itself into globules, when it is in contact with another substance of any kind, to which that fluid has no chemical affinity or attraction, and thus may give that appearance of abhorrence or repulsion, by which chemists have hitherto been persuaded to adopt the idea of a repulsive principle, opposed to that of attraction. Remember, that I am here speaking solely of chemical phænomena. I do not pretend to touch upon mechanical,

magnetical,

magnetical, or electrical attraction or repulsion. These, especially with respect to magnetism and electricity, are perfectly established. Whether there is any mechanical repulsion, independent of these, or the elective attraction, of which I have said so much, may perhaps be disputed.

By this reserve, I think, I obviate your objection to my theory, drawn from Mr. *Melvill*'s, or *Musschenbroek*'s experiment of the needle. Probably, this phænomenon is connected with other principles, than those which chemistry will supply. The suspension of the needle depends upon its exact level position on the surface of the water, and upon the great extent of the surface, when compared with the bulk of the needle and the quantity of water, which it must displace when it sinks. Only the lower side of the needle *touches* the water, and no part of the upper side is wetted at all; for if any part of the upper side be so wetted that either end is depressed, the gravity of the different parts of the needle not acting separately, but in combination, the whole overcomes the resistance of the water, and the needle sinks. In the same manner, many substances, specifically heavier than water, may be made to float upon water by considerably extending the surface. Instances of this fact are so numerous, that they need not be mentioned; and that this is really the case in the experiment under consideration, is obvious from this

this circumstance, that the experiment succeeds best with the finest needles, and if we repeat it successively with different needles, of different sizes, from the smallest to the largest, we shall find the experiment more and more difficult, and at last impracticable; because, although in the smaller needles the bulk of the whole bears comparatively a very small proportion to the extent of their surface; in the larger needles this is not the case, and, therefore, the common law of specific gravity takes place, and the needle sinks in the water. I have paid a good deal of attention to this experiment, both with the naked eye, and with a magnifier, and cannot say that I am satisfied, that Mr. *Melvill* is accurate in asserting, that the needle is not in contact with the water. It forms indeed, as he says, a bed for itself, and depresses the water, but, if we observe minutely, we see that the water touches the lower surface or sides of the needle in many minute points. Why the water does not come into more general contact with the needle, depends probably upon the same cause that disposes water to form globules upon the surface of any highly polished metal, or almost any other inflammable substance: and to the explanation of this point the same principles of chemical attraction, so largely insisted upon in this and my former letter, lend their aid. Water, and all watery fluids, have little or no

attraction

attraction to ſubſtances, which contain a large proportion of phlogiſton. Exceptions might be brought to this poſition, but theſe might be ſo eaſily obviated, that the fact may be admitted as general. Metals particularly exemplify this point; eſpecially if they are highly poliſhed, when their ſurface is ſo perfectly clean, that all thoſe properties, which depend upon the phlogiſton, are moſt obvious and perceptible. If water be poured upon a metal in this ſtate, it is with difficulty made to wet the ſurface, but runs off immediately; or if it adheres, it adheres in a diſcontinued and broken manner. Iron, when wrought to the high temperature of ſteel, peculiarly exhibits this appearance. And ſomething of the ſame kind may be ſuppoſed to obtain, when a ſmall piece of highly poliſhed iron, ſuch as a needle, is laid upon water. Hence the needle, though it is ſuſpended on the ſurface of the water, yet does not, except perhaps in the very loweſt part of it, touch the water, but in a few points.

After all, I would have it perfectly underſtood, that I by no means pretend to deny the facts, which ſeem to evince a repulſive principle; but only preſume to offer my opinion, that in chemiſtry, theſe facts may be explained by the doctrine of ſuperior elective attraction, without the neceſſity of introducing more principles or cauſes, than the facts ſeem to require.

I am

I am glad my remarks on your obſervations met with your approbation. If you think they will at all illuſtrate the ſubject, the Society have my full permiſſion to do what they pleaſe with them; if they ſhould not think they will take more room than they deſerve, I ſhall eſteem their approbation a great honour. But they will ſeem to ſtand inſulated and alone, and perhaps will not be perfectly intelligible, unleſs they are introduced by your obſervations, which were the cauſe of them.

The more I reflect upon the ſubject, the more I am convinced of the power and extent of the influence of attraction in chemical phænomena. In ſolution, it has been admitted ever ſince the time of Sir Iſaac Newton; but there are many other facts, which the late experiments on elaſtic fluids lead us to explain in the ſame manner.

I ſhall, in this letter, only have time to exemplify this poſition, by directing your attention to the circumſtances, which take place in the CALCINATION OF METALS. The experiments of Stahl, &c. convincingly prove, that metals in calcination part with the phlogiſton; and thoſe of Mr. Lavoiſier ſhew, that the calx of a metal, thus deprived of phlogiſton, is not merely an inert earth, but that it is the baſe of the metal united with the aërial acid, or fixed air. It is obvious,

obvious, therefore, that in the procefs, the action of the fire expels the phlogifton from the metallic earth, which then attracts the aërial acid, either floating in the air, or generated by the fire, and continues united with it, till by proper circumftances of application the phlogifton is again brought to act on the metallic calx, and to unite with it; and the aërial acid being expelled the metallic is revived. This, then, is one of thofe cafes of elective attraction, which is varied by the degree of heat. To prove that what I have faid above is juft, let us examine another mode in which metals are deprived of their phlogifton, that is, by folution. A metal, perfectly diffolved in its proper acid menftruum, is held in folution, till fome fubftance is added, which has a greater attraction to one of the ingredients, than they have to each other. Thus, a mild alkali added, attracts the acid, and the metallic earth is precipitated. It is a calx, in all circumftances the fame, as that obtained by perfect calcination; and here it alfo indifputably contains the aërial acid. Indeed, we in a manner fee it take poffeffion of the fixed air in the procefs: for when the alkali is added, and attracts the acid, no effervefcence enfues, though we know the alkali parts with its air, whenever it unites with an acid. It is therefore certainly abforbed by the precipitated calx, and with that, by experiment, we find it united. Again, if we add to a folution of any

metal in an acid, another metal which has a ſtronger attraction for that acid, we know that the former metal will be precipitated, and the latter taken up in its place: and the former will be precipitated, not in a calcined, but in a metallic ſtate; becauſe, in this inſtance, the precipitated metal attracts the phlogiſton, of which the other metal is deprived by its ſolution. It appears therefore that the whole buſineſs of the calcination and reduction of metals depends upon the laws of ſingle or double elective attraction, either ſimply in ſolution, or as they are affected and varied by heat. It appears too, how nearly theſe proceſſes are connected with the doctrine of the elaſtic fluids, with which we are ſo lately made acquainted; for the properties of fixed air are fully eſtabliſhed; and I think, the more recent experiments of Dr. Prieſtley, &c. go near to ſhew, that the phlogiſton of metals, if not exactly the ſame, is certainly nearly the ſame, as inflammable air.

On

On the VOLUNTARY POWER *which the* MIND *is able to exercise over* BODILY SENSATION. *By* THOMAS BARNES, D.D. *Read November* 3, 1784.

THE mutual action of the body and the mind upon each other is felt every moment. The knowledge of the nature, effects, symptoms, and measures of these reciprocal influences, forms no inconsiderable part of the science most necessary to the physician, the moralist, and the divine. It enters deeply into every study, of which either body or mind is the professed subject. And whatever difficulties may attend our inquiries, in the way of mere theory and speculation—difficulties which arise from the narrow limits of the human faculties, and from the absurd attempt to investigate the *essences*, rather than the *operations*, of nature—yet we may acquire from EXPERIMENTS and FACTS a knowledge, clear in its evidences, certain in its principles, and important in its application.

The question which I have proposed to consider, " Whether the mind has any kind of vo-

luntary power over bodily ſenſation," is not merely ſpeculative. It muſt be determined by an appeal to facts; and its influence is, in a high degree, practical and intereſting.

SENSATION is generally defined to be—" A perception in the mind, excited by means of the organs of ſenſe, independently on the will." Thus, when my eye is open, external objects make an impreſſion; nor is it in the power of my mind, if the organ is ſound, to exclude the viſion. In like manner, the touch, the taſte, the ſmell, produce their correſpondent feelings, which the mind paſſively receives, becauſe it is not able to repel them. If this be true of pleaſant, it is ſtill more true of painful ſenſations. Over theſe, it is ſaid, the will has no controul. Senſe will be ſenſe; and pain will be pain, notwithſtanding all our endeavours to blunt the acuteneſs of the one, and the anguiſh of the other.

This ſentiment, though true to a certain point, is not however ſo abſolutely and invariably true, as to admit of no limitation. Many ſtrong facts prove, that the mind is not ſo entirely the ſlave of ſenſe, as to have no power at all to ſuſpend, or, at leaſt, to moderate its impreſſions. In many inſtances, ſhe is able to exerciſe ſome meaſure of that regency, which her nature and office authorize her to maintain over her material and mortal partner.

Senſation

Senſation itſelf is probably different in different perſons. It depends on the ſtate both of the bodily organs, and of the percipient mind.

It is therefore varied, by age, by culture, and by every circumſtance which can affect the temperament, either of the mind, or of the body. Some ſyſtems are naturally more irritable; others more firm. In ſome, all bodily impreſſions are extremely pungent; in others, comparatively languid. The ſame habit is probably not equally diſpoſed, at all times, to the endurance of pain. The temper of the mind, and the ſtate of the nerves, admit of ſo much inequality, that it may demand much greater fortitude to ſuffer calmly, at one period, than at another.

In general, whatever fixes the mind in INTENSE THOUGHT, or rouſes it to STRONG PASSION, makes it leſs ſenſible to organical impreſſion. "How often, ſays Mr. Locke, may a man obſerve in himſelf, that whilſt his mind is intenſely employed in the contemplation of ſome object, and curiouſly ſurveying ſome ideas that are there, it takes no notice of impreſſions of ſounding bodies made on the organ of hearing? A ſufficient impulſe there may be upon the organ; but it not reaching the obſervation of the mind, there follows no perception."* Effects ſimilar to this almoſt

* Eſſay on Hum. Und. Lib. II. Ch. 9. § 4.

every perſon muſt have experienced. For who has not, for a time, forgotten the calls of appetite, the ſenſe of cold, or even the feelings of acuter pains, when his attention has been engaged, by an intereſting ſtory, an affecting oration, or an agreeable amuſement? Of this abſence of mind, and of an inattention to bodily wants ariſing from it, many curious inſtances are given in the Life of Sir Iſaac Newton. Buried in profound meditation, that great philoſopher, we are told, often remained for many hours together beyond the regular time of ſleep, and of meals, equally inſenſible to the demands of food, and of reſt; and ſometimes ignorant whether he had eaten or not.

But theſe effects are ſtill more conſpicuous, when the mind is rouſed to STRONG EMOTION: for PASSIONS, of almoſt every kind, produce a momentary pauſe of ſenſation. How many inſtances have there been, of perſons under ſevere fits of the gout, who, upon ſome ſudden alarm, have entirely loſt the preſent ſenſe of pain, and have made exertions, which, in their crippled ſtate, would have been thought impoſſible? I cannot reſiſt the impulſe of mentioning, to the honour of a Britiſh tar, the ſtrong effects which the love of his country, and the ſpirit of his profeſſion, produced upon the late gallant ADMIRAL SAUNDERS. He had been for ſome time laid up under the extreme debility and langour, which

which often attend that excruciating diſeaſe. A friend, calling one day to ſee him, found him, to his great aſtoniſhment, ſtanding to waſh himſelf in his ſhirt ſleeves, with all the marks of perfect health and agility! Upon inquiring into the cauſe of this ſudden change, the admiral exclaimed, "I have received an order from "government to take the command of a fleet "againſt the Spaniards, and I will not come "back again without ſtriking a blow."—This order was in conſequence of the diſpute relating to the poſſeſſion of Falkland's Iſlands, in 1771. The powerful excitation of this animating appointment gave, for ſome time, a new ſpring to the conſtitution of the brave veteran, and procured him a truce from the miſeries of his ſituation. But ſoon after, the rumors of war dying away, the admiral ſunk down again into languor and diſeaſe.

In this inſtance, the effect was of ſome continuance, becauſe the paſſion called into exerciſe was of a laſting nature. There was a great object before the mind, which continued to ſtimulate its energies for a conſiderable time. In that moſt humiliating and affecting of all human calamities, the loſs of reaſon by madneſs, the feelings of ſenſe ſeem to be almoſt entirely extinguiſhed. The ſcourge, and the knife appear to be equally unfelt. The ſenſe of hunger and of cold is ſuſpended: Providence having kindly

ordained, that where the moral influence of pain cannot be enjoyed, its anguiſh ſhall not be endured.

Violent paſſions, of every kind, during their continuance, produce this effect, of ſheathing the pungency of ſenſation. Fear, and hope, joy, and ſorrow, when ſtrongly excited, equally bring on a temporary inſenſibility: ſo that a perſon ſhall receive blows or wounds, without feeling them. How plainly does this appear in children, who, in anger, or in play, will endure unmoved, what would otherwiſe be felt with the moſt exquiſite keenneſs? In ſome places, the common expreſſions of ſorrow are, to beat the head, to tear the hair, and in Otaheite to ſtrike ſharks teeth deep into their fleſh, thus inflicting wounds, the marks of which appear with indelible impreſſion.

But though all the paſſions have equally a benumbing power, whilſt their paroxyſms continue, yet the effects produced by them *afterwards* on the ſyſtem, with reſpect to the acuteneſs of ſenſation, are widely different. Some paſſions depreſs the mind, weaken the tone of the ſpirits, and render them feelingly alive to every touch. Thus, fear, and ſorrow, after their firſt violence is ſpent, unbrace the nerves, give acuteneſs to pain, and often convert indiſpoſition into diſeaſe, and anguiſh into agony. Other paſſions, on the contrary, induce a firmneſs, a tenſion, a

vigour

vigour of ſoul, which enable it with greater advantage to repel the ſhootings of pain, and the impulſes of appetite. Thus, love and joy, leave behind them a ſucceſſion of pleaſurable and fervent emotions, which, ſettling into habit, ſtill continue to diminiſh the influences of ſenſe upon the elaſtic ſpirit.

In all theſe inſtances, the power of the mind over ſenſation is, if at all, but imperfectly *voluntary.* The paſſions are often excited, without the previous energy of the will. They riſe from ſudden and unexpected cauſes. But the queſtion before us was principally intended to aſk—" Whether the mind has a *direct* and " *immediate* power of diminiſhing ſenſation, by " its *mere volition.* Can it, by its *own energy,* " ſummon a degree of ſtrength and elaſticity, " which ſhall, in any meaſure, leſſen the per- " ception of ſenſitive feeling!"

Numerous inſtances ſeem to prove the affirmative. For how many perſons have, with the full view of pain and ſuffering before them, reſolved to brave their utmoſt rage; and, by means of that reſolution, have really ſuffered much leſs than they would otherwiſe have done? How many, who have enjoyed compoſure and calmneſs amidſt the ſevereſt tortures? The examples of Mutius Scævola, and of Portia, are well known. In both, the mind ſeems to exert a degree of *direct* controul over the ſenſe of pain,

and

and by its own volitions ſo far to weaken it, as to endure, with apparent calmneſs, what would to many appear impoſſible for human nature to ſupport.

We ſmile, indeed, at the pompous and unnatural grimace of an old Stoic, crying out, "O pain, I will never acknowledge thee to be an evil." The attempt to annihilate, or to deſpiſe ſenſation, is doubtleſs much too high; and, in this degree, borders upon frenzy. But ought we not, at the ſame time, to admire the heroiſm of a mind ſtruggling to maintain its liberty, its peace, its ſelf-command, and endeavouring to arm itſelf, by rational and moral influences, againſt the tyranny of appetite, and of ſenſe? And would not this Stoic, who, convinced that it was in his power not to be overcome, is reſolutely determined not to yield, feel leſs pain, than one, who, with a puny and timid ſpirit, endeavours to fly from the enemy whom he dares not meet? Would not this be the caſe with the hardy Spartan, in whom

> "Generous ſcorn
> "Of pain, or danger, taught his early ſtrength
> "To ſtruggle patient with ſevereſt toils!"*

The inſtances of the firm endurance of torture, in the North American Indians, would be abſolutely incredible, if not ſupported by teſtimony,

* Glover's Leonidas, book. I. l. 540

which

which we cannot diſpute, without the moſt ridiculous ſcepticiſm. If their ſenſations were originally equal to ours, one is ready to ſay, it would be impoſſible to acquire that apathy, which they diſcover in ſuch dreadful circumſtances. Let us, then, aſcribe ſomething to natural temperament, to climate, to habit. But ſhall we not, alſo, aſcribe ſomething to the manner, in which they have been accuſtomed to prepare themſelves for ſuch a ſcene? Does not the idea, inculcated upon them from their earlieſt infancy, that it is cowardly to betray any marks of fear, or to utter any complaint, tend to ſtiffen the mind againſt the perception of pain, and to produce ſome part, at leaſt, of this aſtoniſhing inſenſibility?

The Gentlemen of the Faculty, who are preſent, could doubtleſs produce many ſtriking facts, in which the reſolute energy of the mind has manifeſted its power over corporeal feeling. One inſtance, to which many of them were witneſſes, they will recollect with pleaſure. An old ſoldier, at the Mancheſter Infirmary, was a few years ago cut for the ſtone. During that dreadful operation, he uttered no complaint, but appeared calm, and chearful; and, as ſoon as it was over, inſiſted a long time upon "walk-"ing to his apartment, *for the honour of an old* "*ſoldier.*" Did not that ſenſe of honour ſtupify, in ſome degree, the ſenſe of pain, by inſpiring

that

that heroiſm and valour, which are the ſoldier's higheſt characters on the field of battle?

Let us behold a Spaniſh Devotee, upon ſome ſolemn occaſion, laſhing his bare back through the ſtreets with a ſeverity, which almoſt covers him with blood; and, when in the preſence of his miſtreſs, redoubling his ſtrokes with aſtoniſhing fury, ſeeming to feel a glow of conſcious triumph in proportion to the number of his ſtripes, and the violence of his pain. Or, let us turn our eye to the dreadful penances, incredible faſtings, and unmerciful auſterities, which enthuſiaſts of all ages, countries, and religions, have voluntarily endured, and which, thus ſanctified and ſweetened by folly, they have ſeemed hardly to feel. Who can deny, that ſome power reſides in the will, of tempering and diminiſhing corporeal ſenſibility?

If ſuch is the power of *falſe* religion, we ſhall juſtly expect a ſtill ſtronger and nobler influence from that which is *true:* nor ſhall we be diſappointed. Hiſtory teems with inſtances of thoſe, who, in the cauſe of heaven, have manifeſted a firmneſs, a ſublimity, a heroiſm of ſoul —I had almoſt ſaid, worthy of their cauſe. What glorious and animating ſpectacles have been ſeen, of men, of women, even of young perſons, meeting agony and death, in every form of horror which cruel ſuperſtition could invent, with a ſerenity, yea, even with a chearfulneſs of

of foul, which indicated, which demonftrated, the fentiment we are now endeavouring to fupport! We deny not the peculiar aid and prefence of heaven, in thofe moments. But we alfo maintain, that the fpirit of true religion, at all times a rational, a calm, a manly fpirit, tends of itfelf to diminifh the influence of fenfe, and confequently to fheath the pungency of fenfation.

Mental ftrength, like that of the body, depends in no fmall degree, upon habit. He who has never been accuftomed to exert the authoritative dominion of his will over his fenfes, will be puny and tender. The calls of appetite will be, to him, imperious and irrefiftible. Whilft the man, who has been ufed to deny thefe calls, will, with comparative eafe, endure the abfence of fenfitive good, and the prefence of fenfitive fuffering. Hence, the fuperior fortitude with which many of the weaker fex, whofe frames feem to be naturally more irritable to pain, endure the moft dreadful operations. And hence too, that fuperior patience, which mankind often acquire from the long endurance of affliction.

But, whatever judgment we may form upon this queftion, as to the *direct* and *immediate* power of the will over the perceptions of fenfe, —its *indirect* and *mediate* influences cannot be difputed. Whenever we can divert the thoughts

to the other ſubjects, or excite paſſions of different natures, both of which are certainly, in ſome degree, in the power of the mind, we ſo far leſſen the pangs of corporeal pain. The mere diverſion of thought, by whatever means, is of great uſe. It is probable, that the mind cannot receive two perceptions at the ſame inſtant. Every moment, therefore, of ſuch diverſion, is a pauſe from ſuffering. Or, if it be admitted that they may be iſochronous, yet the effect of the one, if of a different kind, will be to diminiſh the other. If, indeed, both the perceptions be of the ſame nature; if, to the torture of bodily pain, be added the diſtreſs of mental anguiſh; the one, compounding itſelf with the other, will exceedingly increaſe the ſenſibility. Compare the feelings of a perſon, ſuffering under ſome violent diſeaſe, from the conſequences of his own guilt—with thoſe of another perſon, ſuffering the ſame affliction, for the teſtimony of a good conſcience, in the cauſe of liberty, or virtue!

When ſenſation is acute, thought will not eaſily be diverted. A ſtronger gale of affection, or of paſſion, will be neceſſary to turn it from its courſe. And we have already ſaid, that paſſions of every kind, whilſt they continue in their ſtrengh, are able to produce this effect. For the moment, there is little difference between joy and ſorrow, anger or fondneſs. The

ſudden

ſudden coming in of a friend long unſeen, or an alarm for his ſafety, if we ſaw him in the inſtant of danger, will equally ſuſpend corporeal feeling. The tooth-ach ſhall fly away, at the preſence of the operator, or at the tidings of ſome happy event. A man, in the paroxyſms of rage, ſhall be as inſenſible to wounds and pain, as the pious martyr at the ſtake.

But let us paſs on beyond the moment of vehement excitation, and then, how great the difference! Among the paſſions, we muſt, firſt, diſtinguiſh thoſe which are of the longeſt continuance; becauſe theſe will produce the longeſt, and conſequently the greateſt, effects. Anger and fear are ſhort-lived impulſes. And, when their violence is ſpent, they induce languor and depreſſion. Hence, though ſenſation may be ſuſpended by them for a moment, it will ſoon return with double pungency. On the contrary, love, joy, and hope are paſſions which live longer in the human breaſt, which leave behind them a firm and animating feeling, and which, therefore, may be expected to produce effects more laſting and important.

Again, we may diſtinguiſh thoſe paſſions, which center themſelves in a narrower, from thoſe which expand to a wider, circle—the ſelfiſh, from the generous and ſublime. Thoſe of the former claſs, after their firſt agitation, are ſo far from blunting the ſenſe of pain, that they irritate

ritate and increaſe it. Thus, fear, and ſorrow, turn the mind inward upon itſelf, and aggravate all its painful ſenſibilities. Anger, which partakes of the nature of fear and of grief, and is, like them ſelfiſh, has the ſame conſequences. It makes the mind ſore, and irritable, and thus whets the edge of ſuffering. Love and gratitude, on the other hand, center the heart on other objects; and, if thoſe objects are great, and amiable, and worthy, inſpire ſublimity and ſtrength. Thus, during their whole continuance, they render the mind leſs paſſively the ſlave of bodily impreſſion. What has not parental affection done, what has it not endured, for the ſupport and defence of its offspring? How amazingly, how long, has it defied danger, and deſpiſed ſuffering, in ſuch a cauſe! What has not the love of country voluntarily conſented to endure!

The ſublimeſt feelings which can govern the human heart, are thoſe inſpired by Religion. For religion carries the ſoul beyond itſelf, and centers all its ſtrongeſt affections upon our Creator, and a better world. If theſe be properly, that is, habitually felt, they will be moſt friendly to that ſelf-poſſeſſion, which braces the mind in all its beſt, and moſt laſting energies. Theſe feelings are permanent in their nature, and large in their object. And how wonderful are often their effects! In that moſt awful hour of diſſolving nature, when the body is racked with

expiring

expiring agonies, faith and hope have often preſented the moſt aſtoniſhing ſpectacles of fortitude, yea even of triumph! The mind, borne upwards towards its Maker, has been able to ſmile in pangs, and to exult in diſſolution.

The moral influence of this ſentiment is highly intereſting and important to us all. It furniſhes an argument in favour of virtue and religion, too conſiderable to be paſſed over in ſilence. For goodneſs, not only inſpires the pureſt ſatisfactions, both in the preſent moment, and in future reflection, but it actually leſſens the degree of bodily ſuffering. It not only increaſes the mental enjoyment, but it diminiſhes corporeal pain. It not only adminiſters the ſweeteſt conſolations under diſeaſe, but it renders the diſeaſe itſelf leſs afflictive.

Born into a world expoſed to ſorrow, and inhabiting bodies liable every moment to various ſufferings, of what value is it, to have our minds in a condition able to ſuſtain, and even to mitigate the ſharpneſs of corporeal feeling! Of what importance, to poſſeſs a ſpirit firm, vigorous, manly! And of what moment, to act under the direction of thoſe principles, and under the impulſe of thoſe affections, which tend to produce ſelf-poſſeſſion, and inward ſtrength!

In order to this, it will be neceſſary to cultivate the habit of ſelf-command. It will be

proper to accuſtom the will to a dominion over ſenſe. And it will be wiſe to cheriſh thoſe affections, which carry the mind beyond itſelf, to objects permanent and noble.

Stoiciſm, which affected to ſecure to its votaries an exemption from evil, and which, in order to this, denied that corporeal pain deſerved the name, not only took its aim too high, but omitted the proper means of atchieving what it is poſſible to attain. It enjoined reſolute ſelf-denial. It eſtabliſhed the dominion of mind over ſenſe. But it did not expand, or elevate the paſſions to their nobleſt objects. Hence, it failed in its effect. For it will follow from what has been obſerved, that a mind which would be firm, muſt be humble. Pride may be indeed a laſting paſſion—but it is ſelfiſh. And there are many moments in the preſent life, when the high ſenſe of dignity muſt yield to humiliating circumſtances, to the conſciouſneſs of weakneſs, and of ill deſert.

But the nobler paſſions, which we have before mentioned, improve by time, and meliorate by habit. The ſoul, whoſe better affections are centered upon proper objects, increaſes in inward ſtrength; it is better fortified againſt diſtreſs and pain; and it is ripening for a world, where pain and anguiſh ſhall annoy it no more for ever.

A NARRATIVE *of the Sufferings of a* COLLIER, *who was confined more than ſeven Days, without* SUSTENANCE, *and expoſed to the* CHOKE-DAMP, *in a* COAL-PIT *not far from* MANCHESTER; *with* OBSERVATIONS *on the Effects of* FAMINE; *on the Means of alleviating them; and on the Action of* FOUL AIR *on the* HUMAN BODY. *By* THOMAS PERCIVAL, M. D. F. R. S. *and* S. A. *&c.*

JANUARY 6, 1785.

IN compliance with the requeſt of this Society, I have obtained an authentic account of the caſe of the unfortunate man, who was ſo long confined in a coal-pit at Hurſt, near Aſhton-under-line. My information, concerning him, has been communicated by Mr. John Lees, of Clarksfield, in that neighbourhood, a Gentleman of probity and good ſenſe, who himſelf very humanely aſſiſted the poor ſufferer, and collected in perſon, or received from thoſe who attended him till his death, the intelligence with which he has favoured me.

On Saturday the fourth of December, 1784, about eight o'clock in the morning, Thomas

 Travis,

Travis, a collier, aged twenty-ſeven, deſcended into the pit at Hurſt, which is ninety yards in depth; and ſeveral other workmen were in readineſs to follow him. But ſoon after he had reached the bottom, the ſides of the pit fell in, and he was cut off from all ſupplies of the external air. The quantity of earth was ſo large, that it required ſix days to remove it: And, on Thurſday, when the paſſage was compleated, the foulneſs of the vapours prevented any one, for ſome time, from venturing into the works. On Friday, ſeveral men entered the coal-mine; but not finding Travis, they conjectured that he had attempted to dig his way into another pit, at no great diſtance. They followed him by the traces of his working; and on Saturday afternoon, about four o'clock, he heard them, and implored their ſpeedy aſſiſtance. When they reached him, he was laid upon his belly, and raiſing his head, he looked at the men, and addreſſed one of them by his name. But his eyes were ſo ſwoln and protruded, that they were ſhocked with the appearance of them; and they prevailed upon him to ſuffer a handkerchief to be tied round his head, aſſigning, as a reaſon, that the light might prove dangerous and offenſive to him. Sal volatile was then held to his noſtrils, and ſoon afterwards he complained of the handkerchief, and deſired them to remove it. They

complied

complied with his requeſt; but his eyes were then ſunk in their ſockets, and he was unable to diſtinguiſh the candle, though held directly before him. Nor did he ever afterwards perceive the leaſt glimmering of light. He aſked for ſomething to drink; and was ſupplied with water gruel, that had been previouſly provided, of which he took a table ſpoonful, every ten or fifteen minutes. When the men firſt diſcovered him, his hands and feet were extremely cold, and no pulſe could be felt at the wriſt. But after he had taſted the gruel, and ſmelled at the ſal volatile, the pulſation of the artery became ſenſible, and grew ſtronger when they had rubbed him, and covered him with blankets. He now complained of pain in his head and limbs, and ſaid, his back felt as if it had been broken. Two men lay by his ſides, to communicate warmth to him; he put his hands into their boſoms; expreſſed his ſenſe of its being comfortable; and ſlept, when he was not rouſed to take nouriſhment. In this ſituation he remained ſeveral hours, till they had compleated a road for his conveyance out of the pit. Whilſt they were carrying him, he had a motion to make water and to go to ſtool, but had not ſufficient power to accompliſh either. At one o'clock on Sunday morning, he was brought to his own houſe; put into bed, well covered, and fed with chicken broth. But his weakneſs

 rendered

rendered him indifferent to nouriſhment. He continued to doze and ſleep; and notwithſtanding his pulſe ſeemed at firſt to increaſe in vigour, it became quick about five o'clock, when he warned them of his approaching end, and expired, without a ſtruggle, in a few minutes. Though Travis had been aſthmatic for many years, his reſpiration was remarked to be clear and eaſy, under the circumſtances above deſcribed. He remained perfectly ſenſible till his death; but had no accurate idea of the duration of his confinement in the pit: For on being interrogated concerning this point, he eſtimated the time to have been only two days, yet added, that he thought thoſe days were very long.

As the foregoing account is defective in ſome intereſting particulars, I have applied to Mr. Lees for further information; and ſhall lay before the Society the Subſtance of the anſwers, which he has returned to my ſeveral queries.

1. I enquired, what food Travis had taken, during the ſpace of twenty-four hours, before he went into the coal-pit; and have been informed, that, on Friday morning, he eat a meſs of water pottage and milk, to his breakfaſt; had roaſted beef and potatoes to his dinner; broth and pudding to his ſupper; and on the Saturday morning, juſt before his deſcent

into

into the coal-mine, a cup of broth and a piece of bread and cheeſe.

2. It is not known whether he had any evacuations in the coal-pit, no marks of them having been diſcovered.

3. There is no doubt that he could ſee, at the time when he was found, as he gave aſſurances of it to the men, notwithſtanding the tumefaction and protruſion of his eyes.

4. The compaſs of the cavity which he had dug, and where he was laid upon his belly, at the time when the men reached him, was three yards in length, and two in width. The ſtratum of coal is about two feet thick. There was a communication between the place where he was confined, and another pit. But as the paſſage was eighty yards long, and in no part more than eight or ten inches wide, the mouth of the pit alſo, into which he had deſcended, being ſtopt, and the body of earth, through which he had dug, thrown behind him, no circulation of air could poſſibly take place. And the truth of this concluſion is evinced by the ſtate of the air, in the other pit, to which this paſſage led. For it was there ſo foul as to extinguiſh the candles, which the workmen carried down, in order to come at Travis, by the way which they denominate, the *air gate*.‡

5. The

‡ The ventilation of this ſubterranean paſſage might, perhaps, have been expedited, and the *mephitis* almoſt

 inſtantly

5. The temperature of the air varies much in coal-pits, even of the ſame depth. No thermometrical obſervations were made on the preſent occaſion; but the ſenſations of Travis ſeem to have indicated coldneſs; and his extremities never recovered their natural warmth. Moiſture always abounds in theſe mines.

6. The weakneſs of Travis prevented him from giving any account of his ſufferings, either from hunger or thirſt. But it was obſerved that he was eager to drink, at the time when he was found.

7. It is certain that Travis had no proviſions with him, in the coal-mine; and that there was not any ſupply of water, except near the mouth of the pit; a place he muſt immediately have quitted, and to which he deprived himſelf of the power of returning, by throwing the earth behind him, in his progreſs. We may therefore preſume, that he paſſed the whole ſeven days of his confinement, without either meat or drink.

inſtantly corrected, by carrying down into it buckets of water, and ſlaking in them a ſufficient quantity of freſh burnt quicklime. The hot ſteam, generated by this operation, it may be preſumed, would have diffuſed itſelf quickly through the whole cavity; the gas would have united with the aqueous vapour; been precipitated with it; and a current of atmoſpheric air would have ruſhed in to ſupply its place.

This

This affecting cataſtrophe coincides, in a ſtriking manner, with an obſervation of Hippocrates, *That moſt of thoſe, who neither eat nor drink for ſeven days, die within that period. And that though they ſurvive, ſo as afterwards to take nouriſhment, their former faſting will prove fatal to them.** Yet it is evident, that the remark, of this faithful recorder of facts, was founded on experience too limited, to give it validity. For we have many well atteſted accounts of longer continued abſtinence, without deſtruction to life. Sir William Hamilton, in his narrative of the earthquakes in Italy, A.D. 1783, mentions a girl, of ſixteen years of age, who remained eleven days without food, under the ruins of a houſe at Oppido. She had a child in her arms, five or ſix months old, who died the fourth day. A light, through a ſmall chaſm, enabled her to aſcertain the time of her confinement, and ſhe gave a very clear relation of her ſufferings. When Sir William Hamilton ſaw her, ſhe did not appear to be in bad health, drank eaſily, but with difficulty ſwallowed any thing ſolid.† In caſes of this kind, is it not probable that the body may be ſupplied with fluids from the external air, by the exertion of ſome extraordinary powers in the lymphatic ſyſtem?

* Hippocrat. de Carnibus. Sect. III.

† Philoſophical Tranſactions, vol. LXXIII. p. 169.

ſyſtem? Thus the Negro, mentioned by Dr. Chalmers, who was gibbeted at Charleſtown, in March 1779, and had nothing given him afterwards, regularly voided every morning, till he died, a large quantity of urine.* The ſpring ſeaſon, in South Carolina, is attended with great nocturnal dews, which being imbibed by the pores of the ſkin, furniſhed the poor Negro with a ſuperabundance of fluids in the night, and a ſufficiency to ſupport perſpiration in the day. I viſited, not long ſince, in conſultation with her kinſman Dr. Eaſon, an elderly lady, who laboured under a very ſevere lientery. Her evacuations, as often happens both in this diſeaſe and in the diabetes, far exceeded in quantity, the liquids which ſhe ſwallowed, or what could be aſcribed to the diſſolution of her ſolids. During five or ſix days before her death, ſhe took no aliment whatever, and only occaſionally moiſtened her mouth, by putting her fingers into it, after they had been dipped in water. Yet ſhe diſcharged a pint of urine once in twenty-four hours. I am inclined to conjecture, that the moiſture of the coal-pit was favourable to Travis; but how long he might have ſubſiſted under ſuch circumſtances, it is not poſſible to determine. It may however be preſumed, that his death was rather accelerated than retarded,

* Chalmers on Fevers, p. 2.

by

by the changes and the hurry which he underwent.

In famine, life may be protracted with less pain and misery, by a moderate allowance of water. For the acrimony and putrefaction of the humours are obviated by such dilution, the small vessels are kept permeable, and the lungs are furnished with that moisture, which is essential to the performance of their functions. Fantonus, a writer of respectable authority, in the estimation of Morgagni, relates the history of a woman, who obstinately refused to take any sustenance, except twice, during the space of fifty days, at the end of which period she died.* But he adds, that she used water, by way of drink, though in small quantity. Redi, who made many experiments, (cruel and unjustifiable in my opinion) to ascertain the effects of fasting on fowls, observed, that none were able to support life beyond the ninth day, to whom drink was denied; whereas one, indulged with water, lived more than twenty days.

Hippocrates has observed, that children are more affected by abstinence than young persons; these, more than the middle aged; and the middle aged, more than old men. Agreeably to this aphorism, Dante is said, by his countryman Morgagni, to have framed the incidents in

* Morgagni de Sedibus et Causis Morborum; Epist. 27.

the

the affecting ſtory of Count Ugolino, a nobleman of Piſa, who was confined, with his four ſons, in the dungeon of a tower; the key of which being caſt into the river Arno, they were, in this horrible ſituation, ſtarved to death. And they are repreſented by the poet, as dying at different periods, according to their reſpective ages.* Travis, being in the prime of life, was fitted to bear the extremities of want better than he could have done in the ſtate of adoleſcence, when the body calls for conſtant nutriment, to ſupport its growth. But of what he felt we are left in uncertainty, as he declined, through weakneſs, to give any relation of it. There are conſtitutions, which do not ſuffer much pain from the calls of hunger. I have been informed,

* On reviewing the ſtory of Count Ugolino, as related by Dante, in his thirty-third Canto, I find that Morgagni is miſtaken in ſuppoſing the incidents of it conformable to the obſervation of Hippocrates. Nor is the poet to be condemned, as deviating from truth or nature; becauſe the power to endure famine muſt depend no leſs upon the ſtate of health and ſtrength, than on the age of the ſufferer. The following lines are copied from the tranſlation of this Poem, by the Earl of Carliſle.

Now the fourth morning roſe; my eldeſt child
Fell at his father's feet, in accent wild,
Struggling with pain, with his laſt fleeting breath,
"Help me, my ſire," he cried, and ſunk in death.
I ſaw the others follow one by one,
Heard their laſt ſcream, and their expiring groan.

by

by a young phyſician from Geneva, that, when he was a ſtudent at Montpelier, he faſted three nights and four days, with no other refreſhment than a pint of water daily. His hunger was keen, but never painful, during the firſt and ſecond days of his abſtinence; and the two following days, he perceived only a faintneſs, when he attempted either bodily or mental exertion: A ſenſe of coldneſs was diffuſed over his whole frame, but more particularly affected the extremities. His mind was in a very unuſual ſtate of puſillanimity; and he experienced a great tendency to tears, whenever he recollected the circumſtance, which had been the occaſion of his faſting. During the whole period, the alvine excretions were ſuppreſſed, but not thoſe by the kidney. And at the cloſe of it, his ſkin became tinged with a ſhade of yellow. The firſt food he took was veal broth, which had ſomething of an intoxicating effect, producing a glow of warmth, and raiſing his ſpirits, ſo as to render him aſhamed of his deſpondency. Perhaps in the caſe of Sextius Baculus, as recorded in the Commentaries of Cæſar, * the extraordinary courage and proweſs which he ſuddenly exerted, might be aided by the exhilarating effect of ſuſtenance, which, under ſuch circumſtances, it is probable he would no longer decline. The fact however evinces, that neither his ſickneſs nor the

* De Bello Gallico, lib. VI.

ſenſations

ſenſations of hunger had been ſo violent, as much to impair his ſtrength of body or vigour of mind. Pomponius Atticus, the celebrated friend of Cicero, who put a voluntary end to his life in the ſeventy-ſeventh year of his age, by refuſing all food, appears to have experienced eaſe from his diſorder, rather than any acute ſufferings by famine. † From the former circumſtance it has been conjectured, that he did not wholly deny himſelf the uſe of water, or of ſome other diluent. But though a few examples of this kind may be adduced, we have the evidence of numerous melancholy facts to ſhew, that the preſſure of want is agonizing to the human frame. "I have talked," ſays an ingenious writer, "with the captain of "a ſhip, who was one of ſix, that endured it in "its extremity, and who was the only perſon that "had not loſt his ſenſes, when they received ac-"cidental relief. He aſſured me his pains, at firſt, "were ſo great, as to be often tempted to eat "a part of one of the men who died, and which "the reſt of his crew, actually for ſome time, lived "upon: He ſaid, that during the continuance of "this paroxſym, he found his pains inſupportable, "and was deſirous, at one time, of anticipating "that death, which he thought inevitable: But

† Sic cum biduò cibo ſe abſtinuiſſet, ſubito febris deceſſit, leviorquè morbus eſſe cæpit: tamen propoſitum nihilo ſecius peregit. Itaque die quinto, poſtquam id conſilium inierat, deceſſit. Corn. Nepos in Vit. Pomp. Attic.

"his

"his pains, he faid, gradually decreafed, after the "fixth day, (for they had water in the fhip, which "kept them alive fo long,) and then he was in "a ftate rather of langour, than defire; nor did "he much wifh for food, except when he faw "others eating; and that for a while revived his "appetite, though with diminifhed importunity. "The latter part of the time, when his health was "almoft deftroyed, a thoufand ftrange images rofe "upon his mind; and every one of his fenfes be- "gan to bring him wrong information. The moft "fragrant perfumes appeared to him to have a fetid "fmell; and every thing he looked at took a "greenifh hue, and fometimes a yellow. When "he was prefented with food by the fhip's com- "pany, that took him and his men up, four of "whom died fhortly after, he could not help "looking upon it with loathing inftead of defire; "and it was not, till after four days, that his fto- "mach was brought to its natural tone; when "the violence of his appetite returned, with a fort "of canine eagernefs."*

To thofe who, by their occupations, are expofed to fuch dreadful calamities, it is of ferious importance to be inftructed in the means of alleviating them. The American Indians are faid to ufe a compofition of the juice of tobacco, and the fhells of fnails, cockles, and oyfters calcined,

* See Goldfmith's Hiftory of the Earth, vol. II. p. 126.

whenever

whenever they undertake a long journey, and are likely to be deſtitute of proviſions. It is probable, the ſhells are not burnt into quicklime, but only ſo as to deſtroy their tenacity, and to render them fit for levigation. The maſs is dried, and formed into pills, of a proper ſize to be held between the gum and lip, which, being gradually diſſolved and ſwallowed, obtund the ſenſations both of hunger and of thirſt. Tobacco, by its narcotic quality, ſeems well adapted to counteract the uneaſy impreſſions, which the gaſtric juice makes on the nerves of the ſtomach, when it is empty: And the combination of teſtaceous powders with it may tend to correct the ſecretion that is ſuppoſed, by an eminent anatomiſt, to be the chief agent in digeſtion, and which, if not acid, is always united with acidity.† Certain at leaſt it is, that their operation is both grateful and ſalutary; for we find the luxurious inhabitants of the Eaſt Indies mix them with the betle nut, to the chewing of which they are univerſally and immoderately addicted. Perhaps ſuch abſorbents may be uſefully applied, both to divide the doſes, and to moderate the virulence of the tobacco. For, in the internal exhibition of this plant, much caution is required, as it produces ſickneſs, vertigo, cold clammy ſweats, and a train of other formidable ſymptoms, when taken in too

† See Mr. John Hunter's paper, on the digeſtion of the ſtomach after death. Philoſ. Tranſact. for 1772.

large

large a quantity. During the time of war, the impreſſed ſailors frequently bring on theſe maladies, that they may be admitted into the hoſpitals, and releaſed from ſervitude. It would be an eaſy and ſafe experiment to aſcertain the efficacy, and to adjuſt the ingredients of the Indian compoſition which I have mentioned. And I am inclined to believe, that the trial would be, in ſome degree, ſucceſsful, becauſe I have repeatedly experienced, in the courſe of my profeſſional practice, that ſmoking tobacco gives relief, in thoſe habitual pains of the ſtomach, which appear to ariſe from the irritation of the gaſtric ſecretions. The like effect is ſometimes produced by increaſing the flow of ſaliva, and ſwallowing what is thus diſcharged.† And I have elſewhere related the caſe of a Gentleman, who uſed to maſticate, many hours daily, a piece of lead, which, being neither hard, friable, nor offenſive to the palate, ſuited his purpoſe, as he thought, better than any other ſubſtance. He continued the cuſtom many years, deriving great eaſe from it, and ſuffering no ſenſible injury from the poiſonous quality of the metal. On mentioning this fact to a navy ſurgeon, he acquainted me, that the ſailors, when in hot climates, are wont to mitigate thirſt, by roll-

† A lady, in this neighbourhood, was relieved of a chronic pain in the ſtomach, by chewing *amara dulcis*, after various other remedies had failed: And I have ſeen good effects from the *calamus aromaticus*, uſed in the ſame way.

ing a bullet in their mouths. A more innocent mean might be devifed; but the efficacy of this evinces, that the falivary glands are for a while, capable of furnifhing a fubftitute for drink. When a fcarcity of water occurs at fea, Dr. Franklin has advifed, that the mariners fhould bathe themfelves in tubs of falt-water: For, in purfuing the amufement of fwimming, he obferved that, however thirfty he was before immerfion, he never continued fo afterwards; and that, though he foaked himfelf feveral hours in the day, and feveral days fucceffively, in falt-water, he perceived not, in confequence of it, the leaft tafte of faltnefs in his mouth. He alfo further fuggefts, that the fame good effect might perhaps be derived from dipping the failor's apparel in the fea; and expreffes a confidence that no danger of catching cold would enfue.

To prevent the calamity of famine at fea, it has been propofed, that the powder of *Salep* fhould conftitute part of the provifions of every fhip's company.† This powder, and portable foup, diffolved in boiling water, form a rich thick jelly; and an ounce of each of thefe articles furnifhes one day's fubfiftence to a healthy full grown man. Indeed, from the experiments which I have made on Salep, I have reafon to believe the fuppofition well founded, that it contains more nutritious matter, in proportion to its bulk, than any

† Lind on the Difeafes of Hot Climates.

other

other vegetable production, now used as food.§ It has the property, also, of concealing the nauseous taste of salt water; and consequently may be of great advantage at sea, when the stock of fresh water is so far consumed, that the mariners are put upon short allowance. By the same mucilaginous quality, it covers the offensiveness, and even, in some measure, corrects the acrimony, of salted and putrescent meats. But, as a preservative against hunger, Salep would be most efficacious, combined with an equal weight of beef suet. By swallowing little balls of this lubricating compound, at proper intervals, the coats of the stomach would be defended from irritation: And as oils and mucilages are highly nutritive, of slow digestion, and indisposed to pass off by perspiration, they are peculiarly well adapted to support life, in small quantities. This composition is superior in simplicity, and perhaps equal in efficacy, to the following one, so much extolled by Avicenna, the celebrated Arabian physician; to whom we are indebted for the introduction of rhubarb, cassia, tamarinds, and senna, into the Materia Medica. "Take sweet al-
"monds, and beef suet, of each one pound; of
"the oil of violets two ounces; and of the roots
"of marsh mallows one ounce: Bray these ingre-
"dients together, in a mortar, and form the mass
"into boluses, about the size of a common nut."

§ See the Author's Essays Medical and Experimental, vol. II.

Animal fat is singularly powerful in assuaging the most acute sensations of thirst; as appears from the narrative of the sufferings experienced by those, who were confined in the black hole at Calcutta. A hundred and forty-six persons, exhausted by fatigue and military duty, were there thrust together into a chamber of eighteen cubic feet, having only two windows, strongly barred with iron, from which, in a close sultry night, and in such a climate as that of Bengal, little or no circulation of fresh air could be enjoyed. In a few minutes, these unhappy wretches fell into so profuse a perspiration, that an idea can hardly be formed of it; and this was succeeded by a raging thirst, which increased in proportion as the body was drained of its moisture. Water! Water! became the universal cry; and an old soldier on the outside, through pity, furnished them with a few skinfulls of it. But these scanty supplies, like sprinklings on the fire, served only to feed and increase the flame. From this experience of its effects, Mr. Holwell, their chief, determined to drink no more; and kept his mouth moist, by sucking the perspiration out of his shirt sleeves, and catching the drops as they fell from his head and face. You cannot imagine, says he, how unhappy I was, if any of them escaped me. He came into the prison without his coat, the season being too hot to bear it: And one of his miserable

miserable companions, observing the expedient he had hit upon, of allaying his thirst, robbed him, from time to time, of a considerable part of his store. This plunderer, whom he found to be a young Gentleman in the service of the East India Company, afterwards acknowledged, that he owed his life to the many comfortable draughts, which he derived from him. Before Mr. Holwell adopted this mode of relief, he had attempted, in an ungovernable fit of thirst, to drink his own urine: But it was so intensely bitter, that a second taste could not be endured; whereas, he assures us, no Bristol water could be more soft and pleasant than his perspiration. ‖ And this, we may presume, consisted chiefly of animal fat, melted by excessive heat, and exuding from the cellular membrane, through the pores of the skin.

Persons who have been accustomed to animal food, are soon reduced, when supplied only with the farinacea. Several years ago, to determine the comparative nutritive powers of different substances, an ingenious young physician, of my acquaintance, made a variety of experiments on himself, to which he unfortunately fell a sacrifice. I have been informed, that he lived a month upon bread and water, and that, under this regimen of diet, he every day diminished much in his weight. But last winter, a student

‖ See Annual Register for 1758, p. 278.

of physic at Edinburgh, confined himself, for a longer space of time, to a pint of milk, and half a pound of white bread daily: And he assures me, that he passed through the usual labours of study and exercise, without feeling any decay of health or strength, and without any sensible loss of bulk ‡ The cutaneous, urinary, and alvine excretions were very scanty during the whole period; and the discharge of fæces occurred only once in a week. In this case, the oily and coagulable parts of the milk probably furnished a larger proportion of aliment, and at the same time contributed to check the waste, by perspiration and other discharges. For oleaginous substances are retained long in the body, by their viscidity. Dr. Russel, in his Natural History of Aleppo, relates, that in those seasons when oil abounds, the inhabitants, by indulgence in it, are disposed to fever, and affected with infarctions of the lungs; maladies which indicate both retention and obstruction. Milk has been suspected, by some, of producing similar effects, though in a slighter degree; and the free use of it has been, on this account,

‡ The following facts, cited by Haller, shews the powers of milk, in small quantities, to support life; but does not ascertain how far it supplies or obviates the waste of the body. *Lactis in diem libra, tres feminæ, à nivis ruinâ obrutæ per* 37. *dies vitam sustentarunt.* HALLER. ELEMENT. PHYSIOLOG. vol. VI. p. 255.

forbidden,

forbidden to aſthmatics. From my own perſonal experience I ſhould preſume, that it is commonly much longer in paſſing by the kidnies, than other liquids; and analogy would lead us to the ſame concluſion, concerning its influence on perſpiration.

Gum arabic might be a good ſubſtitute for ſalep, in the compoſition, which I have recommended. And as it will give ſuch firmneſs to the maſs, as to require manducation, the ſaliva, by this means ſeparated and carried into the ſtomach, would further contribute to aſſuage the ſenſations both of hunger and of thirſt. We are informed, by a traveller of veracity, that the Abyſſinians take an annual journey to Cairo, to ſell the products of their country; and that, as they paſs over vaſt deſarts, the duration of their rout is no leſs uncertain than a voyage at ſea. In the year 1750, the caravan had conſumed all their proviſions, and were under the neceſſity of ſearching amongſt their merchandize, for ſomething wherewith to ſupport life, under that extremity. They found a ſufficient ſtock of gum arabic; and more than a thouſand perſons ſubſiſted upon it ſolely, for the ſpace of two months. The caravan arrived in ſafety at Cairo, without having ſuſtained any extraordinary loſſes, either by hunger or diſeaſe.‡ This gum, combined with ſugar and the whites of eggs, has

‡ Haſſelquiſt's Voyages in the Levant, p. 298.

been lately extolled in France, under the name of PATTIGUMO, as a remedy for catarrhal defluxions. I have ſeen cakes made of theſe ingredients, and think they might very well be applied to the purpoſe of obviating hunger. They are not periſhable in the hotteſt climates, may be carried about the perſon with convenience, and though very tough, are pleaſant to the taſte. In the formula by which they are made, the proportion of ſugar is too large, and that of gum arabic too ſmall, if the maſs be intended to aſſuage the cravings of appetite. According to my information, the receipt is as follows. Take of fine ſugar four ounces, and of gum arabic one ounce: Levigate them well together, and add half an ounce of roſe water, and of the whites of eggs a ſufficient quantity.

In our attempts to recover thoſe who have ſuffered under the calamities of famine, great circumſpection is required. Warmth, cordials, and food are the means to be employed; and it is evident that theſe may prove too powerful in their operation, if not adminiſtered with caution and judgment. For the body, by long faſting, is reduced to a ſtate of more than infantile debility; the minuter veſſels of the brain, and of the other organs, collapſe for want of fluids to diſtend them; the ſtomach and inteſtines ſhrink in their capacity; and the heart languidly vibrates, having ſcarcely ſufficient energy to pro-

pel

pel the ſcanty current of blood. Under ſu h circumſtances, the treatment of Travis was proper, with reſpect to the application of heat, by placing on each ſide a healthy man in contact with him. *Pediluvia* or fomentations might, alſo, have been uſed with advantage. The temperature of theſe ſhould be lower than that of the human body, and gradually increaſed, according to the effects of their ſtimulus. New milk, weak broth, or water gruel ought to be employed both for the one and the other, as nutriment may be conveyed into the ſyſtem, this way, by paſſages, probably the moſt pervious in a ſtate of faſting, if not too long protracted. "A lad at New-market, a few years ago, hav-"ing been almoſt ſtarved, in order that he might "be reduced to a proper weight, for riding a "match, was weighed at nine o'clock in the "morning, and again at ten; and he was found "to have gained near thirty ounces in weight, "in the courſe of an hour, though he had only "drank half a glaſs of wine in the interval. The "wine probably ſtimulated the action of the "nervous ſyſtem, and incited nature, exhauſted "by abſtinence, to open the abſorbent pores of "the whole body, in order to ſuck in ſome "nouriſhment from the air."* But no ſuch abſorption, as this, can be expected, in a ſtate of

* Biſhop Watſon's Chemical Eſſays, vol. III. p. 101.

extreme

extreme weakneſs and emaciation, gradually induced; becauſe the lymphatics muſt partake of the general want of tone and energy. And notwithſtanding the ſalutary effects of wine, in the caſe of the jockey, who, it is likely, had been reduced by ſweating as well as by abſtinence, ſuch a ſtimulant might prove dangerous, and even fatal to one in the ſituation of Travis. I ſhould, therefore, adviſe the exhibition of cordials in very ſmall doſes, and, at firſt, conſiderably diluted. Slender wine whey will perhaps beſt anſwer this purpoſe; and afford, at the ſame time, an eaſy and pleaſant nouriſhment. When the ſtomach has been a little ſtrengthened, an egg may be mixed with the whey, or adminiſtered under ſome other agreeable form. The yolk of one was, to Cornaro, ſufficient for a meal. And the narrative of this noble Venetian, in whom a fever was excited by the addition of only two ounces of food to his daily allowance, ſhews, that the return to a full diet ſhould be conducted with great caution, and by very ſlow gradations.

Though, I fear, my commentary has been already extended to an undue length, yet I cannot cloſe it, without ſoliciting the attention of the Society, to one additional circumſtance, in the caſe of Travis, peculiarly intereſting in its conſequences; viz. the eaſe with which he breathed, for a conſiderable ſpace of time, air

too

too impure for candles to burn in, and which the men, who went in ſearch of him, durſt not venture to inſpire. As he had been long aſthmatic, we may reaſonably conclude, from his ſuffering ſo little, that the commonly received opinion of the *ſuffocating* nature of the mephitis or choak-damp, that it deſtroys the elaſticity of the air, and occaſions a collapſion of the lungs, is without foundation, notwithſtanding all the reſpectable authorities, which may be advanced in ſupport of it. Indeed, from the *phænomena* which attend the extinction of life, in thoſe to whom ſuch vapours have proved mortal, it is evident, that the poiſon acts chiefly on the nervous ſyſtem. The vital principle ſeems to be arreſted, and almoſt inſtantaneouſly deſtroyed; ſometimes even without a ſtruggle, and, poſſibly, without any antecedent pain. Pliny the elder was found, after the fatal eruption of Mount Veſuvius, exactly in the ſame poſture in which he fell, with the appearance of one aſleep, rather than dead: *Habitus corporis quieſcenti quam defuncto ſimilior.** Some perſons killed by foul air in a cellar at Paris, were ſtiff as ſtatues, with their eyes open, and in the poſture of digging.† M. Beaumè relates the hiſtory of a man, who was recovered from apparent death, produced by a ſimilar cauſe, and who aſſerted, that he had felt neither

* Plinii Epiſt. 16. lib. VI.

† Bomaɀè Dict. d'Hiſtoire Naturelle.

pain

pain nor oppression; but that at the point of time when he was losing his senses, he experienced a delightful kind of delirium.* If, under such circumstances, this person could be sufficiently collected to notice his feelings, the testimony is decisive, that *oppression* was not one of them; and consequently, that he could not suffer from *suffocation*. And the account receives some confirmation from what Dr. Heberden says, in his lectures on poisons, that he had seen an instance, in which the fumes of charcoal brought on the same delirium, which hen-bane, and other intoxicating vegetables produce. Abbè Fontana breathed a certain portion of inflammable air, not only without inconvenience, but with unusual pleasure. He had a facility in dilating the breast, and never felt an equally agreeable sensation, even when he inhaled the purest dephlogisticated air. But he suffered greatly from this gratification, in a subsequent experiment: For, having filled a bladder with about three hundred and fifty cubic inches of inflammable air, he began to breathe it boldly, after discharging the atmospheric air, contained in his lungs, by a violent expiration. The first inspiration produced a great oppression: Towards the middle of the second, he was observed to become very pale, and objects appeared confused to his eyes: Nevertheless, he made a third inspiration. His

* Rozier. Observations de la Physique, Jan. 1, 1774.

strength,

ſtrength now failed, he loſt his ſight entirely, fell upon his knees, and ſoon afterwards upon the floor. His reſpiration continued to be effected with difficulty and pain, as if he had a weight upon his breaſt; and he did not perfectly recover before the ſucceeding day. *

In this inſtance, ſome degree of palſy was probably induced, in the nerves of the lungs, by the ſudden action of concentrated inflammable air, conveyed into the veſicles, forcibly emptied of atmoſpheric air. For in ordinary reſpiration, about thirty-five cubic inches of air are inhaled and exhaled; but in a violent expiration, the air diſcharged may amount to ſixty cubic inches. † In the caſe of Travis, it will be remembered, that the air was ſufficiently ſalubrious, when he went down into the coal-pit; that by ſtagnation it became gradually noxious; and that his nervous ſyſtem muſt therefore have been progreſſively habituated to its influence. This is conformable to the obſervations of my friend Dr. Prieſtley, who diſcovered, that if a mouſe can bear the firſt ſhock of being put into a veſſel, filled with artificial gas, or if the gas be increaſed by degrees, it will live, a conſiderable time, in a ſituation which would prove inſtantly fatal to other mice. And he frequently noticed, that when a number of mice had been confined,

* Philoſophical Tranſactions, vol. LXIX, p. 346.

† Ibid. p. 349.

in a given quantity of infected air, a fresh mouse introduced amongst them, has presently died in convulsions.

The same ingenious philosopher seems to have ascertained, that respiration is a phlogistic process; that it is the office of the lungs to carry off the putrid *effluvium*, or to discharge the phlogiston, introduced into the system with the aliment, and become effete; and that the air we breathe acts, on this occasion, as a *menstruum*: We are also assured, by an able chemist, that the quantity of air, phlogisticated by a man in a minute, is equal to that, which is phlogisticated by a candle in the same space of time.* Hence it might be presumed, that like supplies of atmospheric air are essential to respiration and combustion. But the experience of Travis proves the fact to be otherwise.† And though miners generally try the salubrity of the subterraneous air, by the test of a lighted candle, yet we are informed by Mr. Keir, that he has seen them working in the shaft of a coal-pit, several yards below that part where the candle was extinguished. Indeed it was observed by Mr. Boyle, and has since been confirmed by Dr. Priestley, that an animal will live nearly, if not

* See Crawford on Animal Heat, p. 80.

† Dr. Priestley informs me, that he has lately bestowed particular attention on a kind of air, in which a candle burns, but in which a mouse will not live.

quite,

quite, as long in air, in which candles have burned out, as in common air. There muſt be ſome power, therefore, it ſhould ſeem, in the living œconomy, to free the body from redundant phlogiſton, by other emunctories than the lungs: or a ſmall portion of atmoſpheric air may ſuffice, for this purpoſe, in extraordinary emergencies, and for a ſhort period of time. This accommodating faculty, if I may ſo expreſs it, is evidenced in various other inſtances, and particularly in one, no leſs remarkable than that, of which we are now treating: I mean, the equality of temperature, which the body retains, in great extremes of heat and cold. A Ruſſian Boor, in the winter ſeaſon, daily experiences all theſe varieties of air, of heat, and of cold, without inconvenience. When labouring out of doors, he is expoſed to the intenſity of froſt and ſnow: When he retires in the evening, to his hut, which conſiſts only of one cloſe apartment, never ventilated during ſix months, he feeds upon ſalted fiſh or fleſh, and afterwards repoſes on a greaſy mattreſs, placed over an oven, in which billets of wood are burned. In this ſituation, he is literally ſtewed, with his whole family, who live in a conſtant ſteam, not offenſive to themſelves, but ſo groſs and noiſome, as to be ſcarcely ſupportable by a ſtranger. *

* See Phil. Tranſ. vol. LXVIII. p. 622.

The

The atmoſphere of a crowded town muſt, in many reſpects, nearly reſemble the foul air of a Ruſſian cottage. Yet thouſands enjoy in it a tolerable ſhare of health, though we admit the truth of the poet's deſcription, as well as the propriety of his counſel to the delicate and valetudinary;

> Ye who, amid this feveriſh world, would wear
> A body free of pain, of cares a mind;
> Fly the rank city, ſhun its turbid air;
> Breathe not the chaos of eternal ſmoke,
> And volatile corruption, from the dead,
> The dying, ſickening, and the living world,
> Exhaled, to ſully heaven's tranſparent dome
> With dim mortality. *

It has been found, by experiment, that the fumes emitted by almoſt every ſpecies of burning fuel, are fatal to animals, when applied in a ſufficiently concentrated ſtate. I have computed, that three hundred tons of coal are every day conſumed, in the winter ſeaſon, at Mancheſter. The factitious gas, generated by its combuſtion, muſt amount at leaſt to one third of this quantity; it is probable that the ſmoke, proceeding from it, conſtitutes another third part; and both together are capable of occupying a ſpace of very wide extent. Now if it were not for the diſperſion of theſe vapours by wind, the precipitation of them by rain, and the influence

* Armſtrong on Health, Book I.

of

of other caufes, which reftore falubrity to the air, refpiration could not be carried on, under fuch circumftances. And we may obferve that frofty weather, which is generally ferene and without wind, always proves extremely oppreffive, and fometimes even fatal to afthmatic patients, in great cities. Indeed the rate of human mortality bears a pretty near proportion to their magnitude and population: And I have fhewn, in another work,§ that there is an aftonifhing difference between the expectation of life in Manchefter, and the country immediately furrounding it, although the inhabitants of both are fubject to the fame viciffitudes of weather, carry on the fame manufactures, are fupplied with provifions from the fame market, and by their free intercourfe, are almoft equally liable to attacks of fmall-pox, fevers, and other epidemics.

It is evident, therefore, that habit, however it may abate, cannot entirely counteract the baneful operation of bad air. And thofe will feel its pernicious effects moft ftrongly, in every fituation, whofe nervous fyftems are endued with more than ordinary fenfibility. Such perfons I would caution not to indulge their curiofity in the infpection of unwholefome manufactures, nor in vifiting mines, caverns, ftoves, hofpitals, or prifons. Several Gentlemen, in this affembly,

§ Effays Philofophical, Medical and Experimental.

will recollect that the late Dr. Brown suffered, in a very acute degree, by accompanying two foreigners of distinction into the duke of Bridgewater's works, at Worsley. It happened they were the first, who entered the tunnel, on that day. The candles, which they carried with them, were observed to burn very dimly; but neither the passengers nor the boatmen experienced any difficulty in respiration. After remaining in the coal pits a considerable time, they proceeded to Warrington; where Dr. Brown was attacked with violent pains, which shifted suddenly from one part of his body to another. Small purple spots overspread his skin; his throat became so tumefied as to render swallowing difficult; and great prostration of strength, with a low fever ensued. The doctor was subject to the anomalous gout, had once a paralytic complaint of long continuance, and hence we may conclude that his nervous system was endued with peculiar irritability. He was not, however, the sole sufferer; for one of the foreigners was affected with similar petechiæ, but attended with little pain or disorder.

Last year a general alarm was spread, in this neighbourhood, concerning the danger, arising from the noisome effluvia of certain cotton works, to all employed, or who had communication with those employed in them. But the good sense and humanity of the proprietors, aided by

by the authority and patriotic exertions of our magiſtrates, have quieted theſe apprehenſions, by removing, in no inconſiderable degree, the cauſes from which they originated. * And, I truſt, the

* The following Paper, printed and diſtributed by the order of the Magiſtrates, will ſhew the Meaſures taken on this intereſting occaſion.

COUNTY OF LANCASTER.

A repreſentation, of a very alarming nature, having been made by Lord Grey de Wilton, and a great number of the moſt reſpectable inhabitants of the townſhip and neighbourhood of Radcliffe, in this county, to the gentlemen to whom the following letter is directed, of a malignant fever, which was ſuppoſed to have originated in the cotton-works there; they took the liberty of deſiring Dr. Percival, and the other Medical Gentlemen of Mancheſter, to take upon themſelves the trouble of making ſuch enquiries, as they ſhould think neceſſary, in order to aſcertain the cauſes to which it was owing; and the moſt proper methods to be uſed, to prevent the further ſpreading of the contagion. Much to the credit of the phyſicians, they undertook the taſk with the greateſt alacrity; went over to the infected place themſelves; and the following report was the conſequence.

To Samuel Clowes, jun.
Thomas B. Bayley,
Dorning Rasbotham,
and
M. Bentley,
Eſquires.

His Majeſty's Juſtices of the Peace, for the County Palatine of Lancaſter.

 Gen-

the factories are now tolerably well ventilated, supplied with purer oil, and kept in a state of greater cleanliness. Still, however, the delicate and

GENTLEMEN,

We have taken into the most deliberate consideration, your very humane and judicious requisition; and we shall now lay before you the result of our inquiries, concerning those interesting objects, which you have proposed to our investigation. We have fully satisfied ourselves, either from actual observation, or authentic testimony, that a low, putrid fever, of a contagious nature, has prevailed many months in the cotton mills, and amongst the poor, in the township of Radcliffe. We cannot, however, ascertain, whether this fever originated in those works, or was imported into Radcliffe from some other parts of the county. But though this point remain doubtful, we are decided in our opinion—That the disorder has been supported, diffused, and aggravated, by the ready communication of contagion to numbers crowded together; by the accession to its virulence from putrid effluvia; and by the injury done to young persons through confinement, and too long continued labour; to which several evils the cotton-mills have given occasion.

These evils, we trust, are not without remedy; and from the benevolent attention, which the proprietors of the Radcliffe-works have shewn to the sick and infirm under their charge, we may reasonably presume to hope, they will be induced to adopt the following practical regulations, from motives of policy, humanity, and justice, as well as from the respect, which is due to your authority.

I. All the casements of the windows, and the three large western doors of the cotton-mills, should be left open every night: The same regulation should take place, during the recess from work, at noon; and as many casements should be

and valetudinary incur a riſque in viſiting them. For foul air, though it contain not any contagious particles, may yet poſſeſs a virulence, that is capable, in particular habits, of producing fever. Like certain poiſons, it effects an

be kept open, in the hours of labour, as may be compatible with carrying on the operations of the machinery.

II. The caſements are too ſmall; being in dimenſion, only about one ſixth part of the window. They are likewiſe placed high, and parallel to each other—a poſition obviouſly unfavourable to complete ventilation: for the inlet of the air ought to be lower than the outlet.

III. Several fire-places, with open chimnies, ſhould be erected, at proper diſtances, in each work room. The ſtoves, now employed, afford no ſufficient paſſage for the offenſive vapours generated in the rooms; and increaſe the contamination of the air, by the effluvia which they emit. Turf would be the cheapeſt, and alſo a very ſalutary fuel; for it conſiſts, chiefly, of the roots of vegetables; and yields, in burning, a ſtrong, penetrating, and pungent ſmoke, which is likely to prove as good an antidote to contagion, as that of wood is found to be, from long experience.

IV. The rooms ſhould be daily ſwept, and the floors waſhed, at leaſt once every week, with ſtrong lime-water or with water impregnated with the ſpirit of vitriol, or the acid of tar. The walls and ceilings may be ſcraped and whitewaſhed, at firſt, every month, and afterwards, twice or thrice yearly. Lime freſh burnt, and as ſoon as it is ſlaked, muſt be uſed for this purpoſe, and the waſh laid on whilſt it is hot.

V. During the prevalence of the preſent fever, the apartments, ſhould be fumigated weekly with tobacco.

an inſtantaneous change in the nervous ſyſtem, by which the organs of ſecretion are diſturbed, and the ſecretions themſelves corrupted. The common precautions, therefore, ought not to be neglected by thoſe who expoſe themſelves to the influence of ſuch vapours. The valetudinary,

Brimſtone would, perhaps, be more powerful, but, in burning, it yields an acid, which might be injurious to the cotton.

VI. Great attention ought to be paid to the privies. They ſhould be waſhed daily; and ventilated in ſuch a manner, that the ſmell ariſing from them, ſhall not be perceptible in the work-rooms.

VII. The rancid oil, which is employed in the machinery, is a copious ſource of putrid effluvia. We apprehend, that a purer oil would be much leſs unwholeſome, and that the additional expence of it would be fully compenſated, by its ſuperior power in diminiſhing friction.

VIII. A ſtrict obſervance of cleanlineſs ſhould be enjoined on all who work in the mills, as an efficacious mean of preventing contagion, and of preſerving health. It may alſo be adviſeable to bathe the children occaſionally. The apparel of thoſe who are infected with the preſent fever, ſhould be well fumigated, before it is again worn. And the linen, &c. of the ſick, ſhould firſt be waſhed in *cold* water, leſt the ſteams ariſing from heat communicate the diſtemper to the perſons engaged in that operation. Crofter's lye, when it can be procured, is preferable to water. The bodies of thoſe who die of the fever, ſhould be cloſely wrapped in pitched cloth; and interred as ſoon as propriety or decency will permit. Smoking tobacco will be an uſeful preſervative to the ſuperintendants of the works, and to others expoſed to infection, who can practiſe it with convenience.

IX.

ry, eſpecially, ſhould not enter the works with an empty ſtomach, ſhould previouſly fortify themſelves by a glaſs or two of wine, and counteract the ſedative operation of the putrid miaſms by the ſtimulus of hartſhorn, eau de luce, or camphorated vinegar, applied to the noſe.

IX. We earneſtly recommend a longer receſs from labour at noon, and a more early diſmiſſion from it in the evening, to all who work in the cotton-mills. But we deem this indulgence eſſential to the preſent health, and future capacity for labour, of thoſe who are under the age of fourteen. For the active recreations of childhood and youth are neceſſary to the growth, the vigour, and the right conformation of the human body. And we cannot excuſe ourſelves, on the preſent occaſion, from ſuggeſting to you, who are the guardians of the public weal, this further very important conſideration, that the riſing generation ſhould not be debarred from all opportunities of inſtruction, at the only ſeaſon of life, in which they can be properly improved.

We have the honour to be, with the higheſt reſpect,
GENTLEMEN, your moſt faithful,
and obedient humble ſervants,

THOMAS PERCIVAL, M. D.
JOHN COWLING, M. D.
ALEXANDER EASON, M. D.
EDWOOD CHORLEY, M. D.

MANCHESTER,
October 8, 1784.

P. S. Our reſpectable colleagues, Dr. Mainwaring and Dr. Mitchell, are abſent from Mancheſter at this time.

nose. But these volatile substances are to be suffered, as much as possible, to rise spontaneously, and not to be drawn forcibly into the nostrils: For by such inhalation the noxious atoms, floating in the air, will be conveyed to the olfactory nerves, with additional energy; and, being lodged in the schneiderian membrane, they may exert their baneful powers, when, the action of the antidote shall cease. To this cause is to be ascribed that permanency of offensive smells, which makes us sensible to their impression, some time after our removal from their source. And, when this impression is no longer perceived, in the ordinary course of respiration, it may often be renewed by that effort which we denominate snuffing. In this way, I apprehend, and not solely from absorption, the fact is to be explained which Mr. Howard has related, that his phial of vinegar, after using it in a few prisons,

Manchester Michaelmas Sessions, 1784.

The magistrates of this county, assembled in their general quarter sessions at Manchester, impressed with the obligations they are under, have directed the clerk of the peace to give their public thanks to Dr. Percival, Dr. Cowling, Dr. Eason, and Dr. Chorley; and to take care that their letter shall be printed and distributed, so that every part of the community may receive the benefit of their salutary admonitions, a strict attention to which is most earnestly recommended by the court. By order of the court,

James Taylor,
Deputy-clerk of the peace for the county of Lancaster.

became

became intolerably difagreeable to him. When a malignant contagion prevails in hofpitals, goals, or parifh work-houfes, it is to be feared that the preventives, I have recommended, will afford no adequate fecurity. They may, however, be of fome avail: and it would furely be rafhnefs and prefumption to neglect them altogether. But firmer grounds of confidence may reafonably influence the minds of thofe, who are led by official or profeffional duty to incur fuch dangers. " I have been frequently " afked," fays the humane writer whom I have juft quoted, and with whofe words I fhall now clofe this commentary, " what precautions I " ufe to preferve myfelf from infection, in the " prifons and hofpitals which I vifit. I here " anfwer, that next to the free goodnefs and " mercy of the Author of my being, temperance " and cleanlinefs are my prefervatives. Trufting " in *Divine Providence*, and believing myfelf in " the way of my *duty*, I vifit the moft noxious " cells; and, while thus employed, I *fear no* " *evil.*" *

* Howard on Prifons, p. 431, 8vo. 1780.

Result

Result *of some* Observations *made by* Benjamin Rush, M.D. Professor *of* Chemistry *in the University of* Philadelphia, *during his Attendance as* Physician General *of the* Military Hospitals *of the* United States, *in the late* War. *Communicated by Mr. Thomas Henry*, F.R.S. *&c.* *Read October* 5, 1785.

To Mr. THOMAS HENRY.

DEAR SIR,

THE inclosed observations are at your service. Instead of diluting them with theories and cases, which would add only to the number of books, but not to the stock of facts, I send them to you in as short a compass as possible. They are not so fit for the public eye as I could wish; but if you think them worthy of a place in your Transactions, you are welcome to them.

Be assured, Dear Sir, of the great regard of

Your friend and humble servant,

BENJAMIN RUSH.

Philadelphia, *July* 22, 1785.

Result

RESULT *of* OBSERVATIONS, *&c.*

1. The principal difeafes were putrid fevers. Men, who came into the hofpitals with pleurifies, rheumatifms, &c. foon loft the types of their original difeafes, and fuffered, or died, with the putrid fever.

2. This putrid fever was often artificial, produced by the want of fufficient room and cleanlinefs.

3. It always prevailed moft, and with the worft fymptoms, in winter: a free air, which could only be obtained in fummer, always prevented or checked it.

4. Soldiers, billeted in private houfes, efcaped it, and generally recovered fooneft from all their difeafes.

5. Convalefcents, and drunken foldiers, were moft expofed to putrid fevers.

6. The remedies that appeared to do moft fervice in this difeafe, were tartar emetic in the beginning, gentle dofes of laxative falts, bark, wine, (two or three bottles a day in many cafes) and fal volatile.

7. In all thofe cafes where the contagion was received, cold feldom failed to render it active. Whenever an hofpital was removed in winter, one half of the patients generally fickened in the way, or foon after their arrival at the place to which they were fent.

8. The

8. The army, when it lay in tents, was always more ſickly, than when it lay in the open air: it was always more healthy, when kept in motion, than when it lay in an encampment.

9. Militia officers, and ſoldiers, who enjoyed health during a campaign, were often ſeized with fevers upon their return to the *Vita Mollis*, at their reſpective homes. There was one inſtance of a militia captain, who was ſeized with convulſions the firſt night he lay on a feather bed, after lying ſeveral months on a matraſs and on the ground. The fever was produced by the ſudden change in the manner of ſleeping, living, &c. It was prevented, in many caſes, by the perſon lying, for a few nights after his return to his family, on a blanket before the fire.

10. I met with ſeveral inſtances of bubos, and ulcers in the throat, as deſcribed by Dr. Don. Monro: they were miſtaken by ſome of the junior ſurgeons for venereal ſores, but they yielded to the common remedies of putrid fevers.

11. Thoſe patients in putrid fevers, who had large ulcers, and even mortifications on their backs or limbs, generally recovered.

12. There were many inſtances of patients in putrid fevers who, without any apparent ſymptoms of diſſolution, ſuddenly fell down dead, upon being moved; this was more eſpecially the caſe, when they aroſe to go to ſtool.

13. Thoſe

13. Thoſe officers, who wore flannel ſhirts, or waiſtcoats next to their ſkin, in general eſcaped fevers, and diſeaſes of all kinds.

14. Lads under twenty years of age, were ſubject to the greateſt number of camp diſeaſes.

15. The ſouthern troops were more ſickly, than the northern or eaſtern troops.

16. The native Americans were more ſickly, than the Europeans.

17. Men above thirty and thirty-five years of age were the hardieſt ſoldiers in the army. Perhaps this was the reaſon, why the Europeans were more healthy, than the native Americans; they were more advanced in life.

18. The troops from Maryland, Virginia, and North Carolina, ſickened for the *want* of ſalt proviſions. Their ſtrength and ſpirits were only to be reſtored to them by means of ſalt bacon. I once ſaw a private in a Virginia regiment throw away his ration of choice freſh beef, and give ſeven ſhillings and ſix-pence ſpecie for a pound of ſalt meat.

19. Moſt of the ſufferings, and mortality in our hoſpitals, were occaſioned not ſo much by actual want or ſcarcity of any thing, as by the ignorance, negligence, &c. in providing neceſſaries for them. After the *purveying*, and *directing* departments were ſeparated (agreeably to the advice of Dr. Monro) in the year 1778, very few of the American army died in our hoſpitals.

APPEN-

APPENDIX.

EXTRACT FROM THE

MINUTES OF THE SOCIETY.

WEDNESDAY MAY 11, 1785.

THOMAS PERCIVAL, M.D. &c. IN THE CHAIR.

The following REGULATIONS were read:

"THAT a gold medal, of the value of ſeven guineas, be given to the author of the beſt experimental paper, on any ſubject relative to Arts and Manufactures, which ſhall have been delivered to the Secretaries, and read at the ordinary meetings of the Society, before the laſt Wedneſday in March 1785.

"That the adjudication of this premium be referred to the committee of papers; that their deciſion ſhall be made by ballot; and that the medal ſhall be delivered, by the preſident, to the perſon to whom it ſhall have been adjudged, or to his repreſentative.

"That

"That if the perſon, to whom the medal ſhall have been adjudged, be not one of the Society, his name ſhall be enrolled in the liſt of honorary members.

"To encourage the exertions of young men, who attend the meetings of the Society as viſitors, That a ſilver medal, of the value of one guinea be given to any one of them, under the age of twenty-one years, who ſhall within the year, have furniſhed the Society with the beſt paper on any ſubject of literature or philoſophy; and that ſuch adjudication ſhall be made by the committee of papers.

After theſe Regulations had been read, the Preſident thus addreſſed the Society;

GENTLEMEN,

In conſequence of the reſolutions, which have now been read, I am called upon officially to give you information, that the gold medal has been unanimouſly adjudged to Edward Huſſey Delaval, Eſq. for his *Experimental Inquiry into the cauſe of the permanent colours of opake bodies*: And that the ſilver medal has, with the ſame unanimity, been aſſigned to Mr. Thomas Henry, Jun. for his *Review of the Controverſy between Henry Cavendiſh, Eſq. F. R. S. and Richard Kirwan, Eſq. F. R. S.*

F. R. S. relative to the cause of the diminution of common air, in phlogistic processes.

I congratulate you on the satisfaction which you must feel, from these pleasing and honourable testimonies of the benefits resulting from our institution. We have established a Society which, in its views, combines practice with speculation; and unites, with the culture of science, the improvement of the arts. Cast your eyes on the list of communications, which have been recited and discussed in this assembly, and you will clearly perceive the variety, extent, and importance of the objects, which our establishment comprehends. It was my wish and intention to have drawn, from that list, a systematic retrospect of the progressive advances we have made in philosophy and literature. But the short space of a fortnight, to one, occupied as I am, with numerous and pressing engagements, is inadequate to such an undertaking. And I must content myself with offering to your candid attention, the Review of Mr. Delaval's Memoir, which I have delivered, for perusal, to the secretary.

An epitome of Mr. Delaval's Memoir being then read, the President, after the conclusion, addressed the two successful candidates, in the following terms.

ADDRESS

ADDRESS

To Mr. CHARLES TAYLOR.

AS the reprefentative of Mr. Delaval, whofe diftance precludes his perfonal attendance, on the prefent occafion, I deliver to You, in the name of the Literary and Philofophical Society, this Medal, the moft diftinguifhed mark of approbation, which we have to beftow. To merit the honours of Science, and of the Arts, is a juft and noble object of ambition; and to confer them, I am perfuaded, is, at this inftant, felt both as a privilege and a pleafure, by the members of our Inftitution.

When you tranfmit to Mr. Delaval the well earned reward of his defert, let it be accompanied with an earneft requeft, that he will profecute the refearches, he has fo happily begun; and that he will communicate to this Society the further difcoveries, which his induftry and ingenuity may accomplifh.

To Mr. THOMAS HENRY, Junior.

FROM a fage in philofophy, who is above my praife, I turn, with cordial fatisfaction, to

one, whofe proficiency in the knowledge of nature reflects a luftre on his youth. And I prefent to You, in the name of this Society, the honourable mark of diftinction, which has been unanimoufly adjudged to your merit. To fofter rifing genius; to incite the fpirit of emulation; and to give energy to the powers of the human mind, by calling them forth into early exertion, are amongft the moft important objects of our Inftitution. And I cannot better fulfil my official duty, than by indulging the friendly feelings of my heart, in urging you to perfeverance, induftry, and ardour in the purfuits of fcience. Copy the fair example which Heaven, with peculiar favour, has fet before you; elevate your ambition to the true dignity and perfection of your nature; and in every ftudy extend your views to the final defignation of your faculties, which are not limited to this tranfitory fcene, but muft here be trained for Immortality.

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THE END of VOL. II.

ERRATA.

"The writer of the 'Eſſay on Crimes and Puniſhments' begs
"leave to correct a glaring anachroniſm, which has inadvertently
"eſcaped him in note †, page 330. In comparing the Feudal and
"Papal ſyſtems, nothing more was meant, than to point out
"their ſtriking reſemblance in the article of mulcts; whereas the
"turn of the expreſſion ſeems to imply, that *civil* mulcts, which
"had their origin in the earlieſt Saxon times, were copied from the
"*ſpiritual* indulgence granted by the Romiſh church, which was
"one of its lateſt corruptions."

*** *As the Editors reſide at a diſtance from the Preſs, many Errors may probably eſcape their notice, which the Authors of the ſeveral Papers will have the candour to excuſe.*